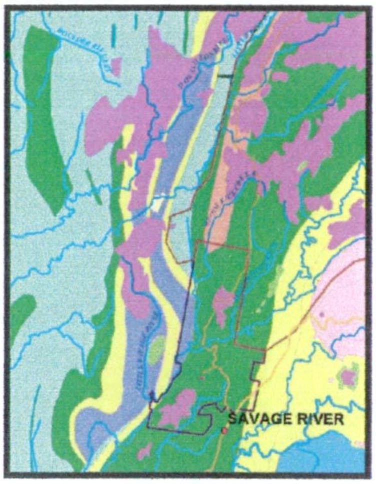
A Conceptual Framework for an Integrated Spatial Environmental Impact Assessment based on GIS



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A Thesis Submitted in Partial Fulfilment of the Masters of Applied Sciences (MAppSc) Program

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STATEMENT OF AUTHENTICITY

This thesis contains no material, which has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution and, to the best of my knowledge and belief, the thesis contains no copy or paraphrase of material previously published or written by other persons, except when due reference is made in the text.

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ABSTRACT

This thesis develops a conceptual framework for a GIS-based integrated spatial environmental impact assessment for mining projects. In recent years, GIS has become wide spread and many specified programs and applications have been developed. While spatial overlay is the most popular GIS analysis in EIA, a range of additional functions is available, which have not been fully utilised, including environmental modelling and web-enabled and mobile GIS. In current EIA theory, strategic and holistic assessment strategies have gained in importance. GIS can contribute towards such strategies through integrated spatial analysis and linked database management. Also, visualisation techniques in GIS can improve communication between all stakeholders and become an essential part of the EIA process. The open cut iron-ore mine at Savage River was chosen as an example to demonstrate the benefits of GIS in EIA. In the hypothetical GIS-based EIA process, illustrative examples are given for analysis of different environmental and socio-economic impacts. Implications for the existing planning system in Tasmania are discussed.

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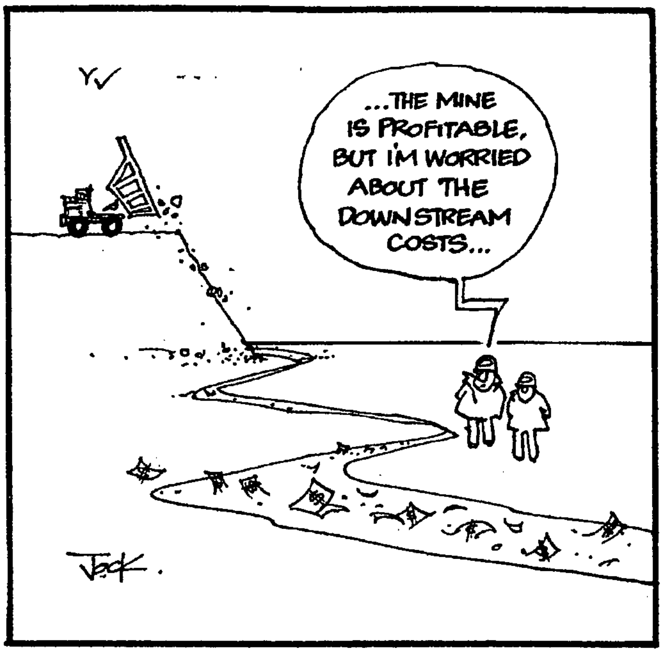
List of Acronyms

ABM	Australian Bulk Minerals
ABS	Australian Bureau of Statistics
AMD	Acid Mine Drainage
ARD	Acid Rock Drainage
ALS	Airborne Laser Scanning
ASDD	Australian Spatial Data Directory
ASDI	Australian Spatial Data Index
BPEM	Best Practice Environmental Management
DELM	Department for Environment and Land Management (now DPIWE)
DEM	Digital Elevation Model
DEMP	Development proposal and Environmental Management Plan
DIER	Department for Industry, Energy and Resources
DPIWE	Department for Primary Industries, Water and Environment
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EMPCA	Environmental Management and Pollution Control Act 1994
EMS	Environmental Management System
EPBC	Environmental Protection and Biodiversity Conservation Act 1999
EP(IP)	Environment Protection and Impact of Proposals Act 1974
EPN	Environmental Protection Notice
ERP	Environmental Rehabilitation Plan
GIS	Geographical Information Systems
ISO	International Organisation for Standardisation
The LIST	Land Information System Tasmania
LUPAA	Land Use and Planning Approvals Act 1993
MRT	Mineral Resources Tasmania
RAP	Recommended Area for Protection
RMPS	Resource Management and Planning System 1993
RPDC	Resource Planning and Development Commission
SPPA	State Policies and Projects Act 1993
SRRP	Savage River Rehabilitation Program
RUSLE	Revised Universal Soil Loss Equation
SECIS	Social, Economic and Cultural Impact Statement
SIA	Social Impact Assessment
TIN	Triangular Irregular Network
TSDD	Tasmanian Spatial Data Directory



Source: Environment Australia 1997

PART A CONCEPTUAL FRAMEWORK

CHAPTER 1 INTRODUCTION

1.1 Background

Mining and mineral processing are important sectors of the Australian economy. Australia has some of the biggest mineral mines in the world (ABS 2003b). Mineral production is widespread throughout the country (see Figure 1-1). Among the minerals, iron ore has had the highest production rate for the last years (Figure 1-2).

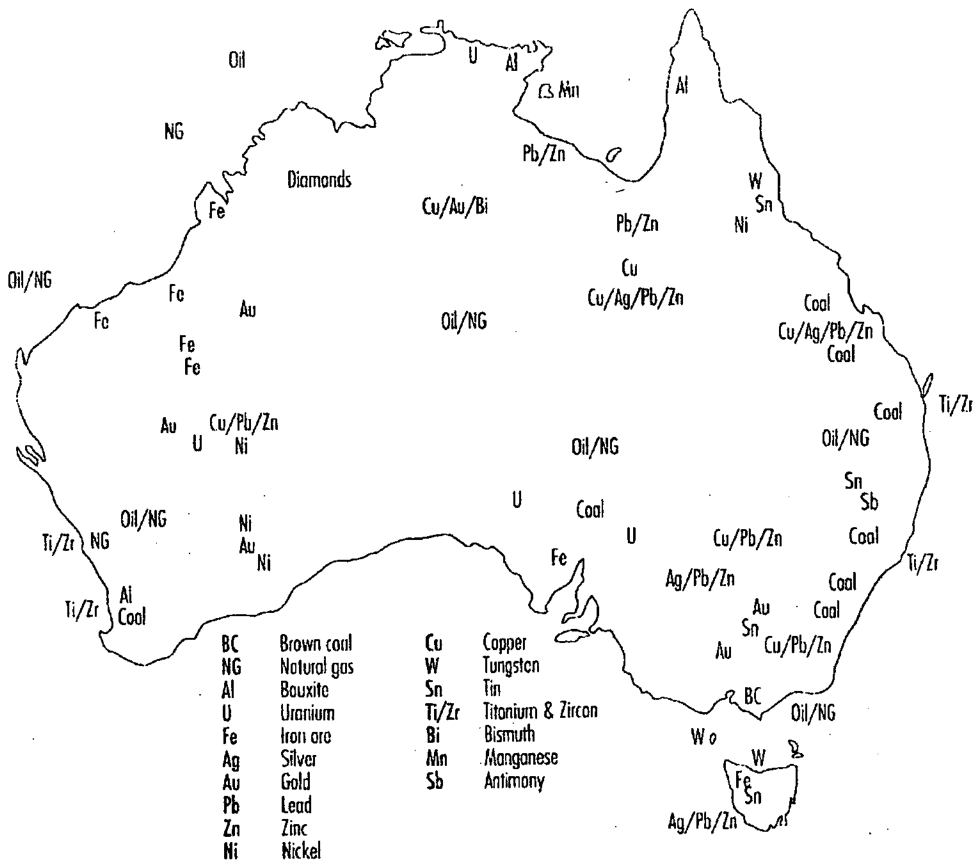


Figure 1-1: Mineral production in Australia (Aplin 2002)

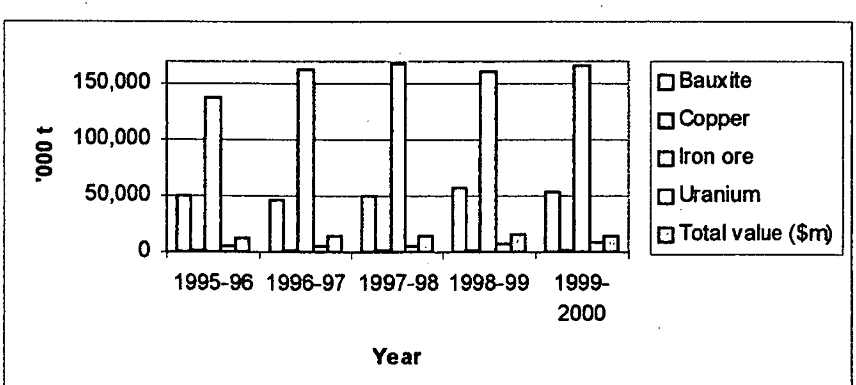


Figure 1-2: Mineral production for selected minerals in Australia (ABS 2003)

Early in the history of mining, mining activities were criticised for their effects on the environment (Turner 2003). In Europe environmental pollution from mining can be traced back more than 1000 years (LFU 1997). A well-known notorious example in Tasmania is the Mount Lyell mine near Queenstown on the West Coast, where mining began in 1896 (Harries 1997). Here, early extraction and processing of minerals has resulted in a denuded landscape, water and soils pollution and stream siltation (SDAC 1996). It was not until the 1970's, that the environment was considered in mining operations (ACF 1972). Today, a large amount of capital is invested into environmental management (see Figure 1-3). Most of the expenditure takes place in rehabilitation and solid waste management. This is especially the case for iron ore mines. The high costs in iron ore mining can be explained by the handling and treatment of large amounts of waste rock (stripping ratio) and rehabilitation of vast areas of open cut mines (Ripley, Redmann et al. 1996; Harries 1997).

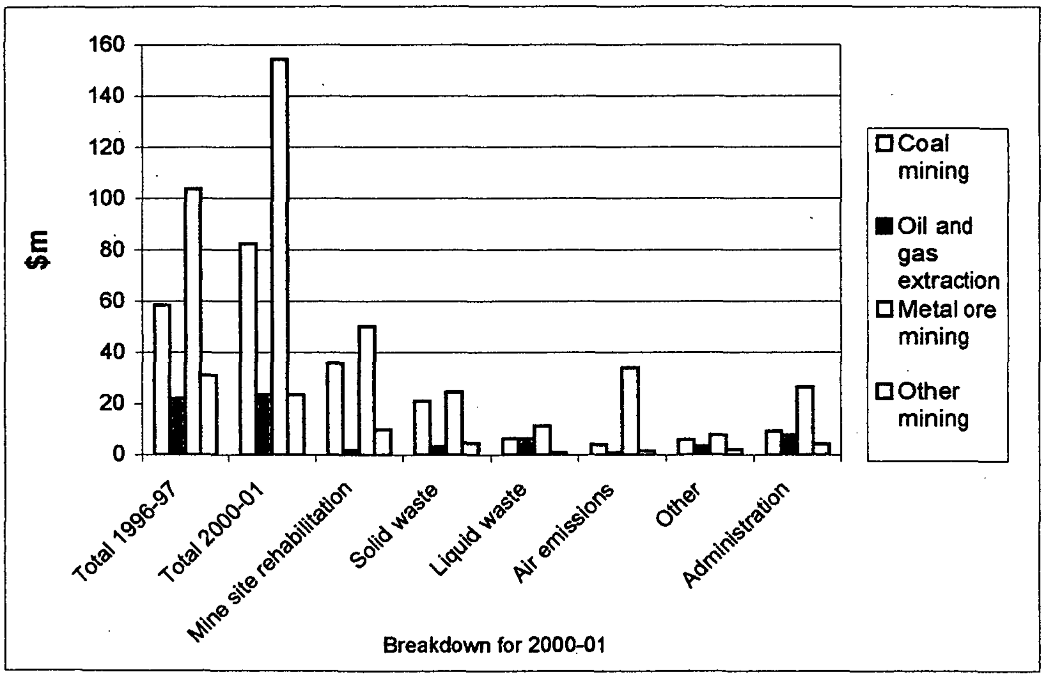


Figure 1-3: Environment protection expenditure in Australia 1996-97 and 2000-01 (ABS 2003)

Use of effective environmental impact assessments (EIA) and integrated environmental management systems (EMS), have the potential to increase the efficiency of mine operations and reduce both environmental and financing costs in the long term. However, experience has shown that in large-scale mining, environmental impacts cannot be completely avoided. The kind and scale of impact varies with the type of mining as well as local climate and topography and range from visible change in the landscape to groundwater and downstream pollution. Acid Mine

Drainage (AMD), which is a concern for mines around the world, is the topic of current research (AusIMM 2003). According to Harries (1997), AUS $ 900 million were spent in Australia for management of mines with potential for acid production over a period of 15 years (between 1982 and 1997). In 2001, a Tasmanian wide survey of AMD for abandoned mine sites was undertaken (Gurung 2001). This survey revealed that 215 abandoned mines produce or have the potential to produce AMD in this state. The study was not only significant from a hydrochemical perspective of assessing AMD but also for spatial analysis and visualisation, as a Geographical Information System (GIS) was used for spatial modelling of AMD.

1.2 Scope and significance of the current study

Although very sophisticated GIS programs have been developed to determine the location and size of ore bodies, for example through 3D geological modelling[1], no fully-fledged GIS application appears to have been developed to date to provide an integrated tool for EIA and environmental management in Australia. One possible reason is the environmental uniqueness of each mine, which makes it difficult to develop general tools for EIA analysis. Another reason is the absence of a comprehensive understanding of interrelated environmental impacts caused by mining. A third reason is the availability of spatial data. The objective of the present study is to develop a conceptual framework, in which GIS is the core instrument for EIA in mining. This can then be used to develop an integrated assessment tool.

1.3 Aims and objectives

The aim of this study is to develop a theoretical framework for an integrated spatial EIA, which can be extended to an EMS. In order to develop such a planning tool, a comprehensive knowledge of environmental processes involved in mining as well as technical aspects of GIS capacity and solutions must be combined. The abandoned iron-ore mine at Savage River has been chosen as a case study for a theoretical framework for a GIS-based EIA. This mine is an example, where EIA needs to consider environmental impacts of abandoned mine areas, a situation that may become more relevant in the future with more difficult to access mineral deposits and the growing capacity to extract lower grades of ore. At the same time, this makes an integrated and co-operative approach more important.

[1] See Geoscience Australia, www.ga.gov.au

The main hypothesis for this study is that the use of GIS improves environmental impact assessment and management in mining by expanding the existing concept of an environmental management system into an "integrated spatial environmental management systems" (ISEMS). A second hypothesis is that the use of GIS enhances communication between the mining operator, governmental agencies and the wider public. This is especially useful, as environmental communication now forms part of an environmental management system (ISO 14063).

1.4 Limitations

The case study focuses on the Savage River mine, which has specific environmental aspects and issues. Although based on data from an existing development proposal and environmental management plan (DPEMP) 1996 and additional sources, the process in this study is largely hypothetical (see Chapter 5 for details). As the project involves many environmental and socio-economic aspects, which would need a team of environmental experts, these different aspects can only discussed broadly and the focus is on GIS methods. Due to the limited available data, a conceptual GIS has been developed rather than a data-based case study. No site inspections and data collections were undertaken, because of the restricted time frame. The literature review revealed that little research has been done on the use of GIS for EIA in mining. Therefore the framework is kept broad and selected examples are given for each EIA component. For illustration purposes maps from other areas have been included. ArcGIS 8.3 was used for display maps.

1.5 Outline

The study is divided into two parts: Theoretical framework (Part A) and case study (Part B). Chapter 2 commences with an overview of the use of GIS as a tool of spatial analysis. It is followed by an overview of methods and principles of EIA for sustainable development. Chapter 3 provides a summary of environmental impacts of mining. It then discusses the benefits of GIS for EIA in mining and its potential for extension as a core part in an Environmental Management System (EMS). In Part B a theoretical framework for a GIS-based EIA for the iron-ore mine at Savage River is developed. In Chapter 8 the implementing of the EIA into the EMS are discussed and recommendations for the Tasmanian planning system using GIS are made. Conclusions and needs for further research are presented in Chapter 9.

CHAPTER 2 THE USE OF GIS AND EIA

2.1 Introduction

GIS has become a well-known tool for spatial analysis, while EIA has become a well-established instrument for sustainable development (Burrough and McDonnell 1998; Harvey 1998). This chapter gives an overview of the uses of GIS for spatial analysis and environmental modelling and EIA methods and use in Australia and Tasmania. The application of GIS as a tool for EIA in mining is discussed in Chapter 3.

2.2 GIS – A tool for spatial analysis

GIS can be broadly defined as a system of "computer based tools to capture, manipulate, process, and display spatial or geo-referenced data" (Fedra 1993, p.35). Burrough and McDonnell (1998) group common GIS definitions into three categories: toolbox-based, database oriented and organisation-based definitions. For this study the early organisation-based definition by Cowen (1988) is considered to be the most appropriate in the context of EIA:

> "A decision support system involving the integration of spatially referenced data in a problem solving environment." (Cowen, 1988 in Burrough and McDonnell, 1998)

This definition emphasises the decision support aspect, which can be seen as the main function of GIS in environmental management in this study. A comprehensive history of GIS is given by Longley, Goodchild, Maguire and Rhind (1999) describing the origin of GIS in digital computing, automated map making, landscape architecture and planning, urban and demographic sciences as well as remote sensing. They explain that the merging of mapping techniques and GIS was a technically easy task, as existing storage and manipulation techniques in different fields were similar. It was more difficult to bring raster and vector data models together because of competition between underlying concepts. It is argued that raster data processes are more "reliable, repeatable and justifiable" (Parker 2003) while vector data operations allow more transparency (DeMers 2000). However this depends on the type of analysis. For example, in hydrological modelling the use of a digital elevation model (raster format) is common (Hutchinson and Gallant 1999). It also allows for integration of remotely sensed data after removal of distortions and geometrical rectification (Estes and Loveland 1999). In landscape character assessment the overlay of digitised information in vector format may be favoured. No single method alone is best. The combination of both is common. For use of satellite data or scanned maps and overlay of vector data, both need to be used. It may be necessary to convert raster to vector and vice versa. This procedure however leads to a loss of quality.

GIS combines established disciplines such as remote sensing, surveying and cartography (Goodchild 1993). A history of these disciplines and state of the art applications are given by Konecny (2003). More detailed information on photogrammetrical methods and integration into GIS can be found in Wolf (2000). A good overview of remote sensing methods and applications is given by Lillesand and Kiefer (2000). Burrough (1998) describes the history of GIS from the natural resource management perspective and Goodchild et al (1993, 1996) the relevance of GIS in environmental modelling. The overlay technique, common in GIS, goes back to McHarg's ground breaking planning technique in "Design with nature" (McHarg 1969), where manual overlays were performed using transparencies to determine environmentally sensitive planning solutions.

In general a GIS consists of four elements: hardware, software, personnel and spatial data (Chou, 1996). The functions can be categorised into: entry, storage, manipulation, analysis, and presentation. Advantages of GIS as compared to the use of paper maps are the capabilities for easier and faster updates and the efficiency in data storage and processing; the storage of multiple attributes for a feature and their relationships (Chou 1997 Goodchild, 1993).

The fundamental characteristic in GIS is its capacity to perform spatial analysis (Chou 1997). Skidmore (2002) argues that the analytical capacity of GIS is the reason for its increasing use in decision-making, planning and environmental management. Technically, spatial analysis may be split into "single layer" and "multiple layer" operations; although most spatial analyses require both. Single layer operations include manipulation, selection and classification; whilst multiple layer operation encompass: overlay, proximity and correlation (Chou 1997).

Analysis methods exist for raster and vector data (see Figure 2-1). For combined analysis either needs to be converted. A common example is a raster Digital Elevation Model (DEM) and overlays using vector data. Some GIS programs offer raster-vector conversion tools. In this process points, lines and polygons of the vector layers are converted to pixels and vice versa. This process usually results in a loss of quality.

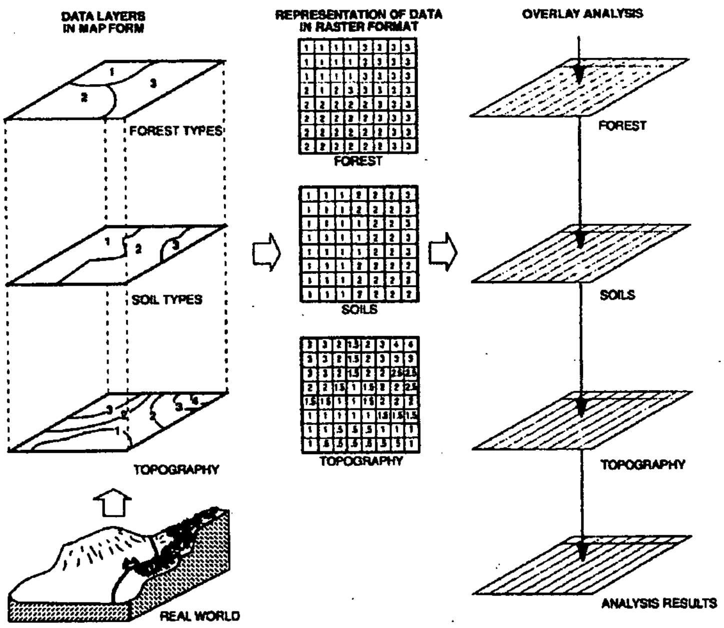


Figure 2-1: Raster and vector overlay in GIS (Aronoff 1989, p. 167)

GIS allows qualitative and quantitative analysis (see Figure 2-2). Both procedures require clear problem definition, identification of data availability, measurement of variables and a multiple step procedure. Difference lies in the use of statistical models in the quantitative approach versus a morphological analysis in the qualitative approach. The latter is more transparent and therefore allows a wider participation and comprehension by non-experts, while quantitative analysis is suited better for complex spatial problems and involves knowledge in statistical model building and is therefore expert-based (Chou 1997). For both methods it is important to take data limitations, measurement type and employed methods into account (Chou 1997).

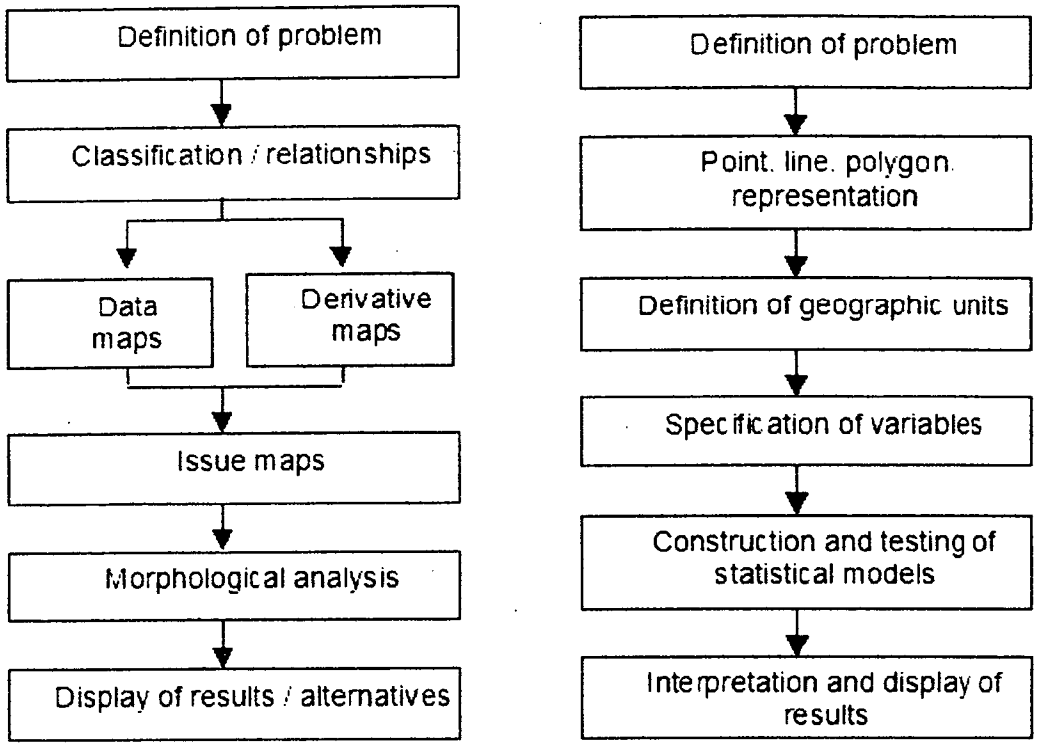


Figure 2-2: Procedure for qualitative (left) and quantitative spatial analysis (right)[2]

In its approximately forty years of existence, GIS has changed significantly in technology and application. While in the 1970s and 1980s, the use of GIS was limited to an exclusive expert community, its main application being in science. The technology has since been developed as a readily available, user-friendly desktop GIS with an extensive range of applications (Goodchild and Longley 1999). A product overview in *GIM* (02/2004) shows that many GIS packages include advanced visualisation functions (3D visualisations, animations, collaborative visualisation), interactive tools (queries, dynamic links, real time maps) GPS links and web-enabled output. A vision for the use of GIS is to provide access to spatial data for display and analysis and this to be possible from everywhere in the world, at any time using stationary computers or mobile devices (Batty 1999). Various data sources (e.g. aerial photos, satellite imagery and airborne laser scanning) are becoming more accurate, higher in resolution and affordable. They replace more and more traditional time and cost-effective surveying methods. Nevertheless, issues of accuracy and scale (i.e. mixing data of varying accuracy), projection and resolution require careful consideration. At the same time traditional thematic cartography should not be overlooked (Caquard 2003).

[2] after Chou 1997

GIS for environmental modelling

One of the most sophisticated uses of GIS for environmental management and planning is environmental modelling. Environmental models are an abstraction or simplification of reality. They allow prediction of future environmental conditions and thus can assist in sustainable development (Skidmore 2002). Large numbers of theories for environmental modelling as well as applications have been developed in GIS. Aspinall and Pearson (1996) have investigated the use of GIS for ecological modelling and Larsen (1999) for monitoring and assessment of sedimentation and water flow. Specific applications have also been developed for soil-landscape modelling (Gessler, Moore et al. 1996; Scull, Franklin et al. 2003) hydrological modelling (Moore 1996; Muller, Cochonneau et al. 2003) and atmospheric modelling (Lee and Pielke 1996). Various hydrological models have been developed including a dynamic hydrological model ("PHASE"), which is linked to a GIS (Gumbricht 2000).

Environmental modelling tools in standard GIS programs to be used in EIA are limited (Openshaw and Alvalides, 1999, Fischer, 1999). One possible reason is seen in the separate development of the essential components of GIS such as data collection methods and environmental models, which in consequence has led to similar products and processes that have not necessarily been compatible (Burrough 1997). Another reason is the gap between GIS and environmental sciences. It is not only a matter of technically linking environmental models with GIS, but as Goodchild (1993) points out, it is also important to understand intrinsic differences in logic and concepts. He argues that GIS models and environmental models do often not match because GIS is representation-oriented using finite elements, whereas environmental modelling can be very abstract and uses mainly continuous elements. Busby (2002) argues that the abundance of data and complexity of environmental models are often beyond the understanding of decision-makers. As Goodchild (1993) points out, GIS tools need to work together in an intelligent way and be easy to use and flexible.

The opinion about whether GIS should aim to fully integrate spatial modelling tools is divided. Some argue that spatial modelling should be outside GIS (Birkin 1996), while others promote modelling within GIS (Aspinall and Pearson 2000). Openshaw and Alvanides (1999) suggests 10 criteria for GIS in order to match with environmental modelling. Among them are: the capacity to be sensitive to the nature of spatial data; to be easy to use; and to have an applied capacity, rather than used for research only. Skidmore (2002) developed a taxonomy of models used for environmental modelling in GIS (see Figure 2-3). This taxonomy categorises each model by the used logic (deductive and inductive) and method (deterministic and stochastic).

Deterministic models are further divided into empirical, process and knowledge-based models. In this taxonomy a model may be part of a combination of approaches. Knowing the logic and the method behind a model may help in understanding its best use and to find similar models (Skidmore, 2002).

			LOGIC	
METHOD			**Deductive**	**Inductive**
	Deterministic	**Empirical**		Regression (USLE), Threshold, Rules
		Knowledge-based	Expert system	Bayesian expert system, Fuzzy system
		Process-based	Hydrological model, Ecological models	
	Stochastic		Monte Carlo	Neural networks

Figure 2-3: Taxonomy of models used for environmental modelling in GIS[3]

One solution to bridge the gap of environmental modelling in GIS is the use of loosely coupled models (Yeh 1999). Complex models such as hydrological modelling are difficult to integrate fully into GIS as they require a large amount of data and are specific in use and conditions (Feng 2000; Gumbricht 2000). For this reason it is argued that hydrological modelling is not likely to become a standard function in GIS (Wegener 2000). In order to provide a stronger linkage, a modular and transparent approach in modelling is necessary (Gumbricht 2000). At the same time, modelling programs such as Matlab[4] increase the number of spatial analysis tools and thus break into the traditional GIS domain. On the other hand, the full incorporation of environmental models into GIS would bring GIS closer to the goal of being an expert

[3] after Skidmore, 2002

[4] The Mathworks, www.mathworks.com

system, which would be of great benefit for those decision makers in EIA, who are not GIS experts.

2.3 EIA - An instrument for sustainable development

Environmental impact assessment (EIA) has been used as an instrument for sustainable development (Glasson, Therivel et al. 1994). EIA has gained wide recognition through the "Rio declaration of environment and development", where it has been adopted as one of the key principles (United Nations 1992; Harvey 1998) EIA can be defined as:

> "The process of identifying, evaluating and mitigating the biophysical, social and other relevant effects of development proposals prior to major decisions being taken and commitments made." (IAIA 1999)

EIA was first incorporated into legislation in the US *National and Environmental Policy Act 1969* (Harvey 1998). Since then it has been introduced into environmental legislation throughout the world, although with many variations (Harvey 1998). An international overview can be found in Wathern (1992). General theory on EIA in English has been well documented for the USA and Europe in particular England (Glasson, Therivel et al. 1994; Morris and Therivel 1996). EIA was introduced in Australia in 1974 with the Environmental Protection (Impact of Proposals) Act (Harvey 1998). A number of different EIA types have been developed since then. Among them are the social impact assessment (SIA), health impact assessment (HIS) and strategic environmental assessment (SEA).

2.3.1 EIA Principles and Methods

According to the basic principles outlined by IAIA (1999), an EIA should among others be:

- Purposive (i.e. informative)
- Rigorous
- Efficient
- Adaptive
- Interdisciplinary
- Credible and transparent
- Participative
- Integrated

The goal of purposive aspects in EIA (i.e. contributing towards protecting the environment and community) and efficiency (i.e. involve minimum financial cost and time) are demanded by environmental legislation and company policies. Less considered are aspects such as interdisciplinary assessment, transparency and public participation. These however can also greatly influence the ultimate goal of environmental protection and efficiency of project development. They are especially necessary to be considered when using more complex processes. At the practical level the EIA should consist of the following steps:

- Screening
- Scoping and baseline studies
- Examination of alternatives
- Impact analysis
- Mitigation and impact management
- Evaluation of significance
- Preparation of environmental impact statement (EIS) or report
- Review of the report
- Decision making
- Follow up

(Beanlands 1992; International Association for Impact Assessment (IAIA) 1999)

A vital part of an EIA process is the decision about the methods and techniques to be used. Common methods in EIA include:

- Checklists
- Matrices
- System diagrams
- Map overlays
- Simulation modelling (Bisset 1992; Harvey 1998)

Simple methods such as checklists and matrices are easy to use and effective for presentation (Glasson, Therivel et al. 1994). Matrices have more than one dimension. For example the *Leopold matrix* combines environmental aspects with potential for environmental harm (Glasson, Therivel et al. 1994). Specialised matrices such as the "ecological impact matrix" developed for mining combine impact type and duration (The Supervising Scientist 2004). System diagrams show interrelationship of environmental characteristics and energy flows between them. This method allows display of the complexity of environmental systems and makes impacts comparable.

It can however be time-consuming and is limited to ecological impacts that can be expressed by energy flows (Bisset, 1992).

The most common GIS function used in EIA is the map overlay. The overlay technique has been criticised as being too simple and subjective. At the same time it is very useful because it is easy to perform and rerun, and can be used to show spatial distribution of potential environmental impacts (Harvey 1998). Patila, Annachhatrea & Tripathib (2002) demonstrated in a comparative survey that remote sensing and GIS can be particularly effective in analysing cumulative impacts by showing effects over time and for a large area, e.g. visualise the source and spread of pollutants.

One example for an EIA in Tasmania, where GIS has been used and well documented, is the Tasmanian Natural Gas Project (Hydro Tasmania 2000). Here, GIS played a central role for determining the route and alternatives for a planned gas pipeline across Bass Strait. A wide range of GIS layers were collected and made accessible for various environmental consultancies.

A major challenge in EIA is the prediction of cumulative (i.e. interrelated and additive effects). Interactions can be between impacts of one project or between the proposed and other projects. Therivel and Morris (1996) divide cumulative impacts into:

- Additive, aggregate, or "nibbling", i.e. the sum of impacts
- Synergistic, i.e. impacts interact and create an impact that is greater than the sum of the individual impacts
- Neutralising, i.e. impacts counteract each other and reduce the overall impact

An example for cumulative environmental impacts are the effects of different mines on a stream (additive). An example for socio-economic cumulative impacts is the potential for employment opportunities and the attraction of more industry and services into the area (synenergistic). While single impacts can be determined by simple methods such as checklists and matrices, cumulative impacts need more sophisticated methods such as overlays, networks and simulation models (Therivel and Morris 1996). While overlay is standard functions in GIS, environmental modelling for simulation is an ongoing area of development (see Section 2.2).

The resulting document of an EIA process is an environmental impact statement (EIS). Findings of an EIA may lead to modification through mitigation measures or in some cases the abandonment of the development proposal (Glasson, Therivel et al. 1994). Decisions on changes or rejection of development proposals depend on the significance of impact. Beside technical issues, information management is one of the major challenges.

2.3.2 EIA in Australia

Little research has been published on EIA methods in Australia. Annandale & Taplin (2003) carried out a comparative study in Australia and Canada discussing impediments of EIA. Harvey (1998) compared the EIA process in the different states and Territories in Australia. Padgett & Kriwoken (2001) reviewed the influence of the EPBC Act 1999 on EIA, Morrison-Saunders, Annandale & Cappelluti (2001) conducted a survey on quality criteria of EIA in Western Australia. The use of EIA in mining is examined by Elliott & Williams (2004), Jarvis and Younger (2000) and Kuma, Younger & Bowell (2002). João (2002) discussed the effect of scale in EIA. Patila, Annachhatrea & Tripathib (2002) compared a conventional with a GIS-based EIA. Hakley (2000) explored the role of the public in EIA and implications for GIS.

The primary Commonwealth legislation, which triggers the need for an EIA, is the *Environmental Protection and Biodiversity Act 1999* (EPBC Act). This legislation replaced several individual acts such as the EP(IP) Act 1974 and enhanced the previous environmental impact assessment procedure by making it more efficient, consistent and transparent (Padgett and Kriwoken 2001). An EIA is triggered if one of the seven matters of national environmental significance is affected. These are the presence of:

- World Heritage properties,
- National Heritage places (from 1 January 2004)
- Ramsar wetlands of international importance,
- Listed threatened species and communities,
- Migratory species protected under international agreements,
- Nuclear actions, and the Commonwealth marine environment.

The decision on whether a proposal requires an EIA is made by the Commonwealth Environment Minister (Environment Australia 2004). The EIA process consists of three stages: a referral, the assessment and the approval. If a "Bilateral Agreement" (section 45(2)) exists between the Commonwealth and the State or Territory, the EIA process is undertaken by the State process. The process can also be carried out by the States or Territories under an "accredited assessment process" (Environment Australia 2004). Under the Commonwealth, the EIA can take one of the four following forms: preliminary documentation, public environment report, environmental impact statement or public inquiry.

EIA in Tasmania

In Tasmania, State and Territory governments are responsible for the granting and administration of exploration and mining licences. In Tasmania the EIA is integrated into the *Resource Management and Planning System 1994* (RMPS). The RMPS represents an integrative planning system with several individual Acts. The overall objectives are:

(a) To promote the sustainable development of natural and physical resources and the maintenance of ecological processes and genetic diversity,

(b) To provide for the fair, orderly and sustainable use and development of air, land and water,

(c) To encourage public involvement in resource management and planning,

(d) To facilitate economic development in accordance with objectives (a), (b), (c) and

(e) To promote the sharing of responsibility for resource management and planning between the different spheres of government, the community and industry in Tasmania (The Law 2004).

Under the RMPS, an EIA can be assessed under three different Acts depending on the significance of impact: the Land Use Planning and Approvals Act 1993, LUPAA (level 1 and most of level 2), the Environmental Management and Pollution Control Act 1994, EMPCA (level 2) or the State Policies and Projects Act 1993, SPPA (level 3). An overview of the EIA process in Tasmania is given in Figure 2-4. Examples for each level are provided in the *Environmental Assessment Manual* (DELM 1996). Level 1 activities are food production, waste disposal or small quarries. Level 2 activities include Mineral Works processing 1 000 tonnes or more per year (e.g. Savage River), metallurgical and cement works. Level 3 are major developments for example, the Basslink electricity cable and mining redevelopment at Mount Lyell. The level of assessment depends on the environmental harm that may be caused by the proposed development or activity. Environmental harm is defined in EMPCA 1994 as "any adverse effect on the environment (of whatever degree or duration) and includes an environmental nuisance" (EMPCA 1994, 5[1]). Development is defined as "the phase of an activity when some form of physical construction or change is occurring, including subdivision and consolidation of land (LUPAA, section 3). An activity is both "the construction and operating phases of development and use of natural resources" (EMPCA 1994). The decision about the level of assessment is made by the responsible planning authority and/or the Board of Environmental Management.

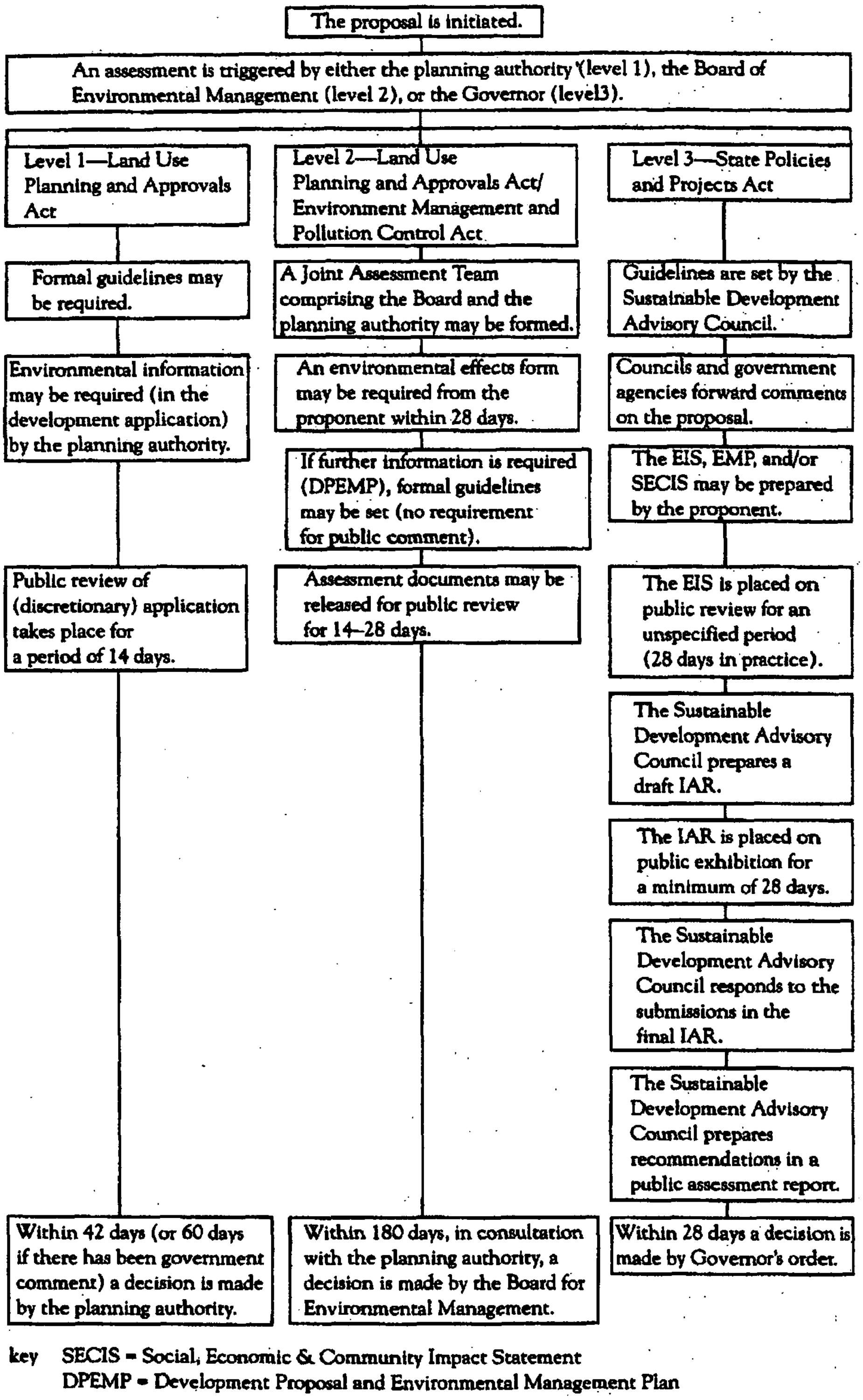


Figure 2-4: The EIA process in Tasmania[5]

[5] Source: Harvey 1998, p. 85

Each level of impact requires a different assessment document to be prepared by the proponent ranging from: "environmental information" to an "environmental impact statement" (EIS), "environmental management plan" (EMP); and/ or, a "social, economic and cultural impact statement" (SECIS). All three levels differ in length of public review period, decision-making authority and time for decision making. A unique aspect in the assessment process in Tasmania is that the public has the opportunity to comment on a draft made by the planning authority (Board) (Harvey 1998). Principles for the EIA process are outlined in EMPCA, Division 1, Part 5. The most important principles are:

- The EIA is the information base for decision-making
- The level of assessment must be appropriate to the significance of the proposed development
- The EIA must be undertaken in accordance with the requirements of the authority assessing the EIA.
- An opportunity for public consultation must be provided during the assessment process

Guidelines for all three levels of proposals are provided in the "Environmental assessment manual" (DELM, 1996). The manual intends to assist planning authorities and addresses mainly level 1 activities, although a wider interest is expected (DELM, 1996).

One important aspect of EMPCA is the use of best practice standards in environmental management. This is defined as "the management of the activity to achieve an ongoing minimization of the activity's environmental harm through cost-effective measures assessed against the current international and national standards applicable to the activity" (EMPCA, 4[1]) and is controlled by the following measures:

(a) strategic planning by the person carrying out, or proposing to carry out, the activity;

(b) administrative systems implemented by the person, including staff training;

(c) public consultation carried out by the person;

(d) product and process design;

(e) waste prevention, treatment and disposal. (EMPCA, 4[2])

More specific standards for best practice for example in mining have been published by "Environment Australia" (former "Environmental Protection Agency").

Requirements for spatial information in EIA are few. Mining operators are required to provide information in mainly descriptive format. Information is required on: staging of proposed works, disposal of waste and current and proposed land use as well as scientific and cultural information (MRT 1999). DELM developed a guideline for Level 1 development proposals in mining (DELM 1996). Information recommended to be mapped in a scale of 1:25,000 include: areas of proposed mine lease; any residence within 1km; any existing pit workings within the proposed lease not already shown on the map and areas to be disturbed (DELM 1996). In addition, a working map in a scale of 1:100,000 should show information on aspects such as boundary of the mining lease within 100 m of the pit, proposed location and size of the pit, the locations of any rivers or creeks within 100 m of the pit, the locations of overburden heaps, topsoil stockpiles, settling ponds and tailings ponds. Requirements for level 2 and level 3 proposals are outlined in project specific guidelines by the *Board of Environmental Management* and the *Sustainable Development Advisory Council* (Harvey 1998).

The Exploration Code of Practice 1999 provides guidelines on map format and information content. Map scales should be consistent with standard map scales (1:25,000, 1:50,000, 1:250,000), datum and projection, include base data and a comprehensive legend. The content refers mainly to the display of geophysical properties and geology.

2.3.3 Environmental Management System

The EIA, which results in a single document, has been criticised as being static (Harvey 1998). One possibility to make the EIA process more dynamic is to incorporate the outcome of the EIA in an environmental management system (EMS). This is required by EMPCA (4[2a]) and by best practice environmental management in mining (EPA 1995 c). Prototypes of environmental management systems have been developed by the International Organisations for standardisation (ISO 2002). The EMS ISO 14001 consists of a range of standards such as the standard for "Environmental Performance" (ISO 14062), "Environmental Performance Evaluation" (ISO 14030), "Life-cycle Assessment" (ISO 14040) and "Environmental Auditing" (ISO 19011) (see Figure 2-5). A new item, which is currently being developed by ISO is "Environmental Communication" (ISO 14063). This will ensure that environmental performance is properly communicated to internal staff and external stakeholders. One important aspect of ISO 14063 is improved transparency and documentation of EIA processes and environmental issues. ISO has also developed more specific standards for monitoring the quality of air, water, soil and noise.

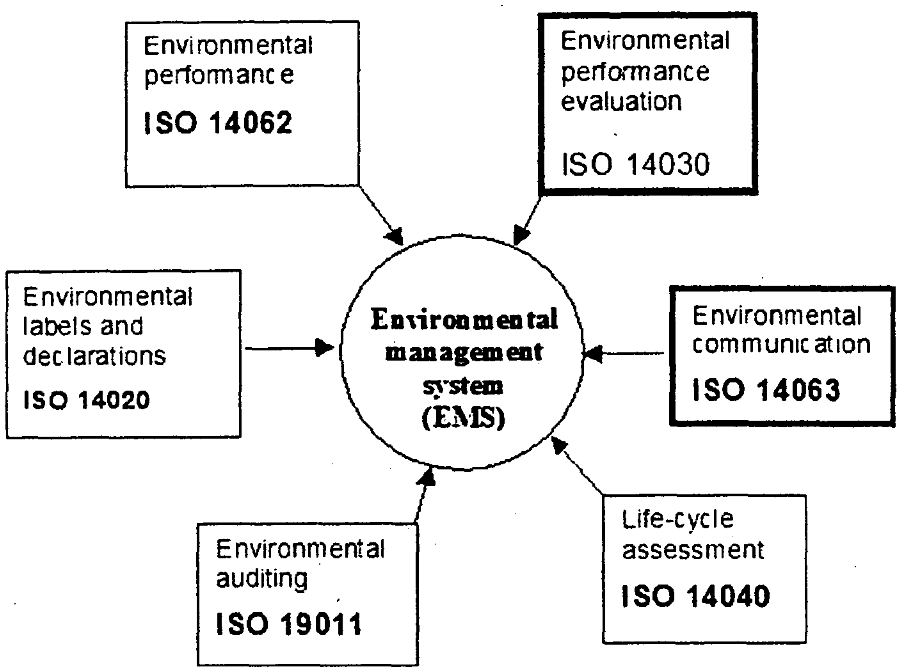


Figure 2-5: EMS and its most important components developed by ISO[6]

The establishment of an EMS is likely to be required for a mining permit as was the case at Savage River (ABM 1996).

2.4 Conclusions

As a synthesis of several disciplines such as remote sensing, surveying and cartography GIS provides great opportunities for use in EIA. During the last ten years, GIS has become a user-friendly desktop program with a range of sophisticated functions. Mobile and Internet GIS expand the use further towards a multifunctional system. One major advantage of a GIS approach for EIA is that collected data, for example for water quality, can be used for impacts on flora and fauna. Thus it allows a more integrated assessment. The most common GIS-function used in EIA is spatial overlay. Other functions such as networks and 3D modelling have become standardised in GIS but are less known in EIA. Environmental

[6] International Standardisation Organisation (ISO) (2002). ISO and the environment. Environmental management.

modelling is possible but extensive programming knowledge is required to fully integrate environmental models or, if a loosely coupled system is used, a good understanding of the outside model is needed. A better integration of environmental modelling and simulation would be the basis to develop an expert system, which is flexible and easy to use for non-GIS experts. Such a system for EIA must be able to simulate single source as well as cumulative impacts. In addition, it needs to be flexible enough to be extended for use in environmental management in accordance with ISO and other standards during mining operation.

CHAPTER 3 THE USE OF GIS FOR EIA IN MINING

3.1 Introduction

Mining operations can affect many aspects of the environment including vegetation, landscape and groundwater. Environmental effects vary depending on the climate and local conditions. In addition the history of the place can influence future impacts. In many cases, the effects of mining last longer than the mining operation and many long-term environmental effects caused by remaining pits, tailings and waste rock dumps are not well understood to date (Sengupta 1992; Harries 1997). At Mount Lyell near Queenstown, where mining has been undertaken for more than hundred years, environmental pollution in the form of acid drainage is an ongoing concern (McQuade, Johnston et al. 1995).

3.2 Best practice in Mining

In recent years management of mining has sought to balance profit against environmental damage. A major global event, which had consequences for planning of natural resources and the primary industries was the *UN Conference on the Human Environment* in Stockholm in 1972 (UN 1972). Here a new understanding of natural resources and the need for nature conservation was developed. Principle 2 states:

> "The natural resources of the earth including the air, water, land, flora, and fauna especially representative samples of natural ecosystems must be safeguarded for the benefit of present and future generations through careful planning or management, as appropriate." (UN 1972).

Followed by other global conferences and outcomes such as the *Brundtland Report* in 1987 (UN, 1972) and the *Rio Declaration* in 1992 (WCED 1987), the idea of sustainable development was strengthened and resulted in greatly increased regulations throughout all industries including the mining industry. In Australia several Acts were introduced including the *National Conservation Strategy* in 1983, the *National Strategy for Ecologically Sustainable Development* in 1992 to the *Environment Protection and Biodiversity Act* in 1999 (IIED 2002). This also impacted on the mining industry. Mining was subject of environmental concerns (Australian Conservation Foundation (ACF) 1972; Geological Society of Australia and Australian

Institute of Geoscientists 1991). In response, the mining industry in Australia took a pro-active approach by introducing best practice standards for environmental management systems and the *Australian Minerals Industry Code for Environmental Management 1996* (ABS 2003). This code promotes best practice standards in mining including the use of an environmental management system (EMS) according to ISO 14000. The Environmental Protection Agency (today Environment Australia) has published a series of booklets on best practice standards in mine planning and management. These include specific mining related issues such as waste dump design (Environment Australia 1998) and water management (Environment Australia 1999 b). As well they cover issues of EIA (EPA 1995 f), environmental management systems (EPA 1995 e) and community consultation (EPA 1995 g).

Today as a result, the mining industry in Australia is subject to a range of governmental and self-regulated environmental controls. White (1997) argues that because the mining industry is working within many regulations and constraints today, it can be seen as the most conscious of all land users. The vision for the mineral industry is to achieve "outstanding environmental, social and economic performance" (Mineral Council of Australia 2000).

Sometimes the term *"sustainable mining"* as defined in the "Berlin Guidelines" can be found (Environment Australia 2002). As mining resources are not renewable the term seems from a broader holistic perspective as being misleading. "Sustainable mining" in reality can only be used in the context of sustainable use of resources to ensure the availability of resources for the future of the industry and the people (ABS, 2003). In 2002, a study was carried out by the World Business Council for Sustainable Development (IIED 2002). This study was initiated by the Global Mining Initiative (established by worlds leading mining and metal companies) and with support of the International Institute for Environment and Development (a London-based NGO). In addition, several national studies including in Australia were carried out (IIED 2002). The findings of the study in Australia included the need to increase public participation and to develop strategic directions.

This aspect of public involvement has also been addressed in the best practice standards, recommending that community consultation should begin early to promote a two-way exchange of information and solutions (EPA 1995 g). The aspect of community consultation has recently been strengthened by the "Code of environmental management 2000" (Mineral Council of Australia 2000).

3.3 Mining regulations in Tasmania

In Tasmania the idea of sustainable development was adopted in 1993 with the Resource Management and Planning System as a planning framework and the *Environmental Pollution and Control Act 1994* as the controlling legislation. Legislation most relevant to the mineral industry in Tasmania is:

- Mineral Resources Act 1993 (Tas.)
- Mining (Strategic Prospectivity Zones) Act 1993 (Tas.)
- Mineral Resources Development Act 1995 (Tas.)
- EPBC Act 1999 (Cwth.)
- Environmental Management and Pollution Control Act 1994 (Tas.)
- Land Use Planning and Approvals Act 1993 (Tas.)
- State Policies and Projects Act 1993 (Tas.)
- Aboriginal Relics Act 1975 (Cwth.)
- National Parks and Wildlife Act 1970 (Cwth.)
- Threatened Species Protection Act 1995 (Cwth.)
- Historic Cultural Heritage Act 1995 (Tas.)
- Crown Lands Act 1976 (Cwth.)
- Regional Forest Agreement and Land Classification Act 1998 (Tas.)
- Dangerous Goods Act 1976
- Environmental Protection Act 1973
- Pollution of Water by Oil and Noxious Substances Act 1987
- Water Management Act 1999

(Tas. = Tasmania, Cwth. = Commonwealth)

Codes relevant to mining are:

- Mineral Exploration Code of Practice 1999 (4^{th} ed.) (Tasmania)
- Quarry Code of Practice (Tasmania)
- Code for Environmental Management 2000 (Australia)

Mining legislation is generally outside the *Resource Management and Resource System 1994* (RMPS) (The Environmental Defenders Office 1999). The *Mineral Resources Development Act 1995* can for example include areas of private property, State Forest and some types of reserves for exploration. However permits require environmental impact assessments and compliance with policies, codes and best practice standards (MRT 2004). With the *Regional Forest Agreement and Land*

Classification Act 1998, which amended the *National Parks and Wildlife Act 1970*, the *Crown Lands Act 1976*, and the *Forestry Act 1920,* the list of areas for exploration was reviewed in respect to nature conservation (MRT 2000). *Regional Forest Agreement and Land Classification Act 1998* has particular relevance to CAR reserves (comprehensive, adequate and representative forest reserve system), which under the new Act are all subject to the *Mineral Exploration Code of Practice 1999* (RFA clause 81, MRT 2000). Also, the environmental impact assessment and environmental management conditions as required by the EMPCA 1994, SPPA 1993 and/or the Mineral Resources Development 1995 (RFA clause 81, MRT 2000). CAR reserve areas with high wilderness value are processed under the State legislation to minimise effect of mineral exploration and mining activity. Rehabilitation is required and aims "to achieve world's best practice and to return the site to its wilderness condition" (RFA clause 82, MRT 2000, p.20).

Several standards and guidelines have been developed. Among them are:

- AS2243-10 Chemical storage (ABM 1996)
- AS/ NZS ISO 14000 – Environmental Management Systems

ANZECC/ARMCANZ and ANZECC/NHMRC guidelines for water and soil quality (ACMER, Environment Australia 1999 a; 2004)

3.4 Environmental impacts of mining

Environmental impacts of mining have been classified in different ways. For example, Down and Stocks (1977) group the environmental effects by their impact on man. Law (1984) distinguishes between cultural, geological and biological impacts. The Environment Protection Agency (now Environment Australia) lists 14 environmental issues relevant to mine planning including aspects of the natural environment such as air, water, flora and fauna as well as socio-economic aspects such as noise and visual effects (EPA, 1995 c). Ripley et al (1996) group the environmental effects according to different mining products. Other authors concentrate on environmental problems related to a specific type of mining such as coal mining (Sengupta 1992; Hannan 1995). Most common are categorising the environment in EIA such as:

- Landform and landscape
- Rocks and soils
- Hydrology
- Flora and fauna

- Socio-economic and cultural impacts

3.4.1 Landform and landscape

Landform and landscape can be seen as different aspects, but are closely related. Landform is the physical shape of an area resulting from factors such as: past land-forming processes geology, climate, hydrology, soil and ecology. Landform plans are often based on engineering solutions (Turner 2003). Landscape, on the other hand, refers to human experience of an area in the form of visual perception, subconscious response and conscious thought and interpretation. For an overview of the history of landscape evaluation see (Yoji 1999).

While landform is commonly addressed in EIA, particularly for risk assessment and safety, landscape aspects, i.e. the character of the area, its natural integrity and cultural history have less priority. This might however change with rising importance of landscape values (RPDC 2003). Goodey (1994) argues that landscape is becoming more important in statuary planning as public interest in landscape continues to rise. In Tasmania landscape values relating to mining have gained significant importance with closures of mines at Queenstown. This mining area is a well-known example of where landscape values have been hotly debated in respect to mining (Sustainable Development Advisory Council (SDAC) 1996; Aplin 2002).

3.4.2 Rocks and soils

Environmental impact depends largely on the type and form of the mineral extracted. Iron for example is extracted in different ore forms (oxides, carbonates, silicates and sulphides). The most toxic residuals are those from sulphide ores, which in the presence of water readily form acid (Ripley, Redmann et al. 1996). Environmental effects also vary with the surrounding rock type and structure. Some rock types containing carbonates have a neutralising capacity. Physical aspects such as grain size and permeability as well as hydrochemical properties such as acid generating potential are important for predicting acid mine drainage (Wels, Lefebvre et al. 2003). Static tests such as net acid generation (NAG) tests and kinetic tests (leach tests) are undertaken to determine the acid generation potential. While the NAG test is designed for field use, kinetic tests are performed in laboratories (Harries 1997). The process for testing acid mine drainage potential of rocks is described by Miller (1992).

One important impact related to rock and soils is erosion, which occurs predominantly with surface mining. The process involves weathering, solution corrosion, and transportation. Erosion can be split into wind and water erosion effects. Wind erosion causes air pollution (dust) and can be problematic near settlements (Environment Australia 1998), especially in drier climates. Water erosion may be caused by raindrops (splash erosion) or flowing water (gully or sheet erosion). Potential damage by erosion caused by water includes filling lakes and ponds, blocking stream channels, destroying aquatic habitats and carrying pollutants e.g. heavy metals, bacteria and viruses (Law 1984)

Aspects of erosion are critical in designing large pits and waste dumps. The erosion of topsoil is a particular concern, because topsoil contains fertile material and is essential for vegetative growth, and as well because topsoil production can be a very long process, often occurring over many centuries (Law 1984). Restoration of topsoil and re-vegetation is therefore vital in the rehabilitation process. If waste material is moved to a permanent position, slope angles and stabilisation measures need to be considered (Environment Australia 1998).

3.4.3 Hydrology

The extraction and processing of ore can affect water quality (Ripley, Redmann et al. 1996). Prediction of impacts on water requires comprehensive understanding of the interrelated processes of the water cycle including precipitation, surface runoff, infiltration, transpiration and evaporation. Effects on the water cycle include contamination of surface and groundwater through pollutants, and changes of surface flow volume and velocity through transport of sediments (Law 1984; Ripley, Redmann et al. 1996).

The type and significance of impact depends on a combination of factors such as annual precipitation, type of rocks and soils and vegetation cover. Transport by streams depends on the type of stream, which can be ephemeral (usually dry), intermittent (flowing in certain seasons) or perennial (flowing continually all year round (Law 1984). The infiltration rate depends on the type of rock, soils and vegetation cover. Sandstone for example is known as a good aquifer whereas most clays have lower infiltration rates (Law 1984).

3.4.4 Flora and fauna

Mining impacts on nearly all aspects of natural biological life (Law 1984). Prevention and measurement of effects require the understanding of individual as well as overall aspects such energy flow, species diversity, resilience of ecosystems, and plant succession, process and rates (Ripley, Redmann et al. 1996). The scientific discipline, which explains the relationships between living organisms and their environment, is ecology. It can therefore provide the understanding of the joint effects of mining on flora and fauna (Morris, 1996). An ecosystem can be defined as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Convention on Biological Diversity, United Nations Environmental Program 1992). One important assumption in ecology is that all elements in an ecosystem depend on each other and that a change of one has an effect on the others. The goal of ecological management is to maintain a high level of biodiversity (Morris, 1996). *Restoration ecology*, a relatively recent developed subfield of ecology, seems to provide the most suitable approaches for restoration of biodiversity in areas disturbed by mining. Davies and Slobodkin (2004) define restoration ecology as "the process of restoring one or more valued processes or attributes of a landscape". Restoration is a complex process, because linkages and changes in ecosystems are non-linear and difficult to predict (Anand and Desrochers 2004). As restoration of the original ecosystem is not always possible, decisions on priorities often include social values (Davis and Slobodkin 2004).

The most important legislation for conservation of ecosystems and biodiversity in Australia is the EPBC Act 1999. On a state level this is incorporated by EMPCA (EMPCA 1994, Part 1, 1(a)). Other strategies in Tasmania, which aim to increase biodiversity and are therefore indirectly related to mining impacts are: the Threatened Species Strategy, Tasmania's Nature Conservation Strategy, the Private Forest Reserves Program and the Regional Forest Agreement (RPDC, 2003). The "Freshwater Project" is a state-wide environmental monitoring program undertaken by DPIWE to monitor water quality and biodiversity of Tasmanian streams.

A well-known example for a restoration project after mining in Tasmania is Mt Lyell, where large areas of forest were logged for open-cut mining and the would used in smelters (Farrell and Kratzing 1996). Revegetation is the first step to restore biodiversity of this area. However the bare but colourful rocky landscape has been part of the tourism image of the area and prevented successful reforestation projects. Another example is the rehabilitation of Savage River, where copper tolerance to fish was used as a threshold level (DPIWE, 2003). Fish species can indicate the health of an ecosystem, as presence of adequate fish populations usually indicate that animals of the lower food chain have recovered as well. However, some more sensitive macro-invertebrate species have not been successfully re-introduced despite having reached a satisfactory copper threshold level (DPIWE, 2003). The restoration of fish communities is also an example, where social values need to be considered, as fishing contributes to recreational values of the region.

3.4.5 Socio-economic and cultural impacts

The effects of mining operations on socio-economic values depend on the scale of change brought by the development with respect to existing conditions. An additional mine nearby other well established mines or other industries and associated services is likely to be integrated into the existing socio-economic structure with less impact, compared to a new mine in a remote area. The latter will need to establish new housing and service and result in a socio-economy with high dependency on a single mine operator. Alternatively this may lead to broader regional effects through integration with an existing but widespread infrastructure of nearby towns. Socio-economic impacts are becoming more relevant for EIA in mining. The principles of the *Code of Environmental Management 2000* include aspects of employment, community values and cultural heritage. By including these aspects in the EIA significant impacts can be predicted and avoided for the surrounding communities (Nicholls 2002).

3.4.6 Acid Mine Drainage

The categories above are not sufficient to explain interrelated effects such as acid mine drainage (AMD). AMD is a complex interaction of physical, hydrological, geochemical and microbiological processes, which can occur in base metal, coal and uranium mining (Harries 1997; Wels, Lefebvre et al. 2003). If the ore body contains high amounts of sulphide minerals, AMD may occur. Acid drainage can be defined as the oxidisation of sulphidic minerals (pyrite) from exposure to atmospheric conditions (Environment Australia 1997). This is a common natural weathering process, but is often accelerated in mining when large volumes of sulphide rich material are broken up and exposed (Environment Australia 1997). AMD from oxidation of sulphidic mine wastes is one of the main environmental issues in the mine industry today (Harries 1997). Treatment methods include: neutralisation, removal of sources, isolation of sources (e.g. use of clay cover), water management and re-vegetation (Miedecke 1996). Neutralisation of pollutants has been recommended at Mount Lyell (west coast of Tasmania). At the Rosebery mine (west coast of Tasmania) wetlands and settling ponds are being used for the treatment of tailings. Clay covers or encapsulations are methods for isolation of sources of AMD. A comprehensive overview of AMD and treatment methods can be found in Lottermoser (2003). An Australian wide study on AMD was undertaken by Harris (1997).

Acid producing processes can cause longterm ecological impacts. National and international programs and networks have been established to target the many existing abandoned mines (see Sec. 4.3 for definition) including AMIRA International in Australia, the US Abandoned Mine Land Program (AML), the Canadian Mine Neutral Drainage 2000 Program (MEND 2000) and the International Network for Acid Prevention (INAP). For detection and prioritising rehabilitation, remote sensing methods such as magnetic, electromagnetic and radiometric airborne surveys have been successfully employed (Smith et al. 2000). The prediction, mitigation and treatment of AMD are topics in ongoing research. A yearly international conference (ICARD) has been established to exchange research results and practical experience.

Interrelated and cumulative environmental effects, such as AMD can best be addressed with dynamic methods and flexible components rather than a rigid step-by-step process based on pre-defined categories. A GIS-based method is discussed in Section.

3.4.7 Mining Impacts in Tasmania

Tasmania has a long history of mining, which has left its marks from minor traces through to major enduring changes in the environment. Figure 3-1 shows current locations of mines and mineral processing in Tasmania.

Specific environmental aspects of mining in Tasmania are:

- High annual rainfall in mining areas on the West coast
- Mountainous and incised topography
- Remoteness
- Proximity to World Heritage Areas
- Contribution of mining to the overall economy
- Re-activation of abandoned mines
- Lack of environmental data

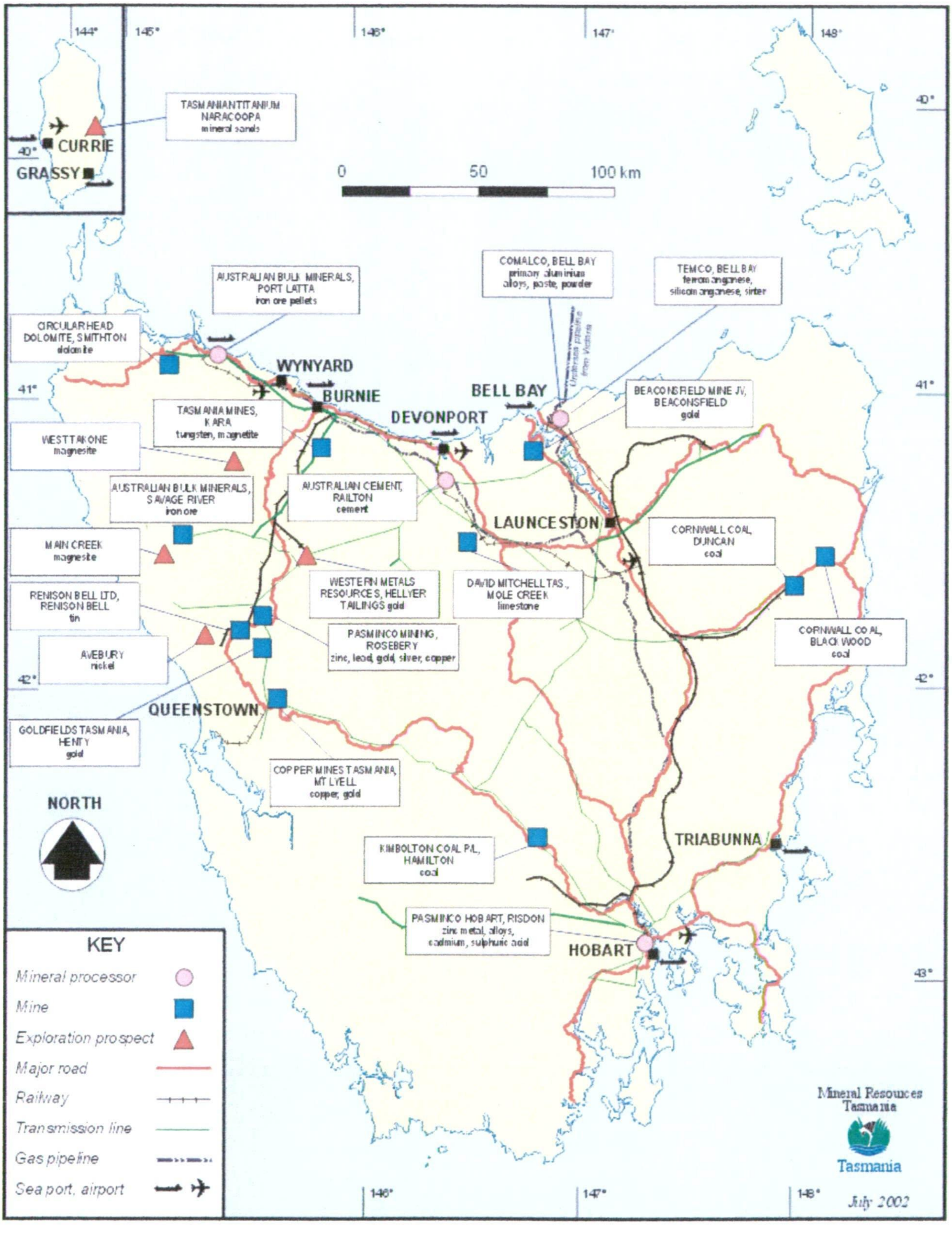


Figure 3-1: Mines and mineral processing in Tasmania[7]

[7] Mineral Resources Tasmania (MRT) (2004).

Most mining in Tasmania takes place in the mineral rich mountainous west coast, which is located in a region of high rainfall climate and lowest temperatures (see Figure 4-2). Water causes physical erosion of stockpile ore and subsoils leading to increased production of acid from the mine site and the transport of sediments and pollutants over great distances (Miedecke 1996). Apart from AMD, siltation can cause a problem as seen at the King River south of Queenstown (SDAC 1996). As well, high rainfall provides large quantities of run-off from mine sites and this presents management difficulties in the containment of polluted water, which may sometimes need to be released into surrounding streams. On the other hand, the presence of excess water has some benefit in dilution of pollutants if mixed (naturally or artificially) with neutralising reagents. Incised drainages and steep slopes also result in difficulties through increased intensity of run-off and stream velocities. Environmental damage at Mount Lyell include impact on landscape, vegetation, topsoil, hydrology and water quality in rivers and harbour (McQuade, Johnston et al. 1995).

The west coast mines of Tasmania are remote from major population centres and are often located in wild and natural areas close to national parks and World Heritage Areas. As many mines pre-date these conservation classifications, they sometimes border directly onto wilderness areas, highly regarded for their pristine natural character (Sustainable Development Advisory Council (SDAC) 1996; Resource Planning and Development Commission (RPDC) 2003). The contrast in environment between mine sites and operations and wilderness areas nearby is usually extreme, and emphasises the sensitivity of mine site environmental management. This is clearly obvious in the visual contrast between the mine and surrounding native vegetation. A major reason for this is that mining has been a key industry in Tasmania since early settlement and was responsible for opening up of the remote west of the state. During 2002/2003 it contributed $ 4.5 million of the state income in royalties. In 2003, mining employed 3,990 people (MRT 2004).

Another typical Tasmanian problem in mining is the high number of abandoned mine sites, which are an ongoing concern for pollution of streams and rivers (DELM, Sengupta 1992; 1996; Harries 1997; Kaden and Schramm 2000). Mining in Tasmania started in many areas long before EIA and before environmental management was an integral part of mine planning. Environmental monitoring was therefore not carried out in earlier times and details about mine operations are difficult to track down. Some mines have ceased operation (historic and abandoned minesites) and some have been re-activated under a different owner (e.g. Savage River, Zeehan). Abandoned mining lands are defined as "areas or sites of former mining activity for which no individual, company, or organisation can be held responsible" (MRT, 2004). Such sites are also known as 'derelict' or 'orphan' mines. Some mining agreements for re-development exclude previous pollution from rehabilitation of current mining (for example Goldamere Agreement 1996).

Re-activation of abandoned mines is a major challenge for EIA, as areas of proposed and historic mining overlap and amounts of pollution for proposed mining are difficult to predict to separate existing from previous operations. Lack of knowledge of historic pollution is a further barrier for the EIA by the new owner (ABM, 1996). The mine at Mt Lyell in Tasmania is one example where renewal of mining activities have initiated a major research program on how to measure and reduce contamination from historical mining (McQuade, Johnston et al. 1995; Miedecke 1996; Harries 1997). The most limiting factor of this research program was the lack of good quality monitoring data from the past (McQuade, Johnston et al. 1995). Difficulties for an EIA at a re-activated minesite include:

- The absence of any planning for rehabilitation during the original operation
- The degraded state of the sites (bare and denuded, absence of topsoil)
- Inadequate documentation of the operations, which may present hazards including unmarked workings, unstable embankments, and unexpected chemical contamination
- The sites often have heritage significance
- Sites may have become the habitat for native fauna and relict populations of native flora, sometimes as a direct result of mine disturbance (MRT 2004)

Harris (1997) carried out an Australian wide research on AMD of abandoned mine sites including mines in Tasmania. Gurung (2001) conducted a Tasmanian wide survey on AMD of abandoned mines. Koehnken did research at the Pieman and King River including the upper Macquarie Harbour (SDAC 1996). A further study was undertaken by Davies et al (2000) with the aim of defining thresholds for recovery of the ecosystem of the lower King River and upper Macquarie Harbour (SDAC 1996). Local surveys have been carried out by the Centre of Ore Deposits at the University of Tasmania. Parr (1997) examined acid mine drainage in the Zeehan mine district. This resulted in a AMD map of the area based on field survey and catchment data.

Field survey was carried out at 20 selected sample sites at tributaries of the Henty River. Evans, Cooke and Davidson (in press) examined groundwater quality at the Rosebery mine. Although major research projects such as the "Acid Drainage Reconnaissance Report" (Gurung 2001) have been carried out and rehabilitation programs started or planned [i.e. Mount Lyell with the *Mount Lyell Acid Mining Reduction Act 2003* and at Savage River (DPIWE 2003)], the lack of base data to predict AMD and other waterborne pollution is still a major problem in Tasmania (Lockley, Pollington et al. 2003; Resource Planning and Development Commission (RPDC) 2003). The difficulties associated with abandoned mines and the gap in knowledge call for a more strategic approach to environmental impacts assessment, taking into account regional aspects and the history of the site.

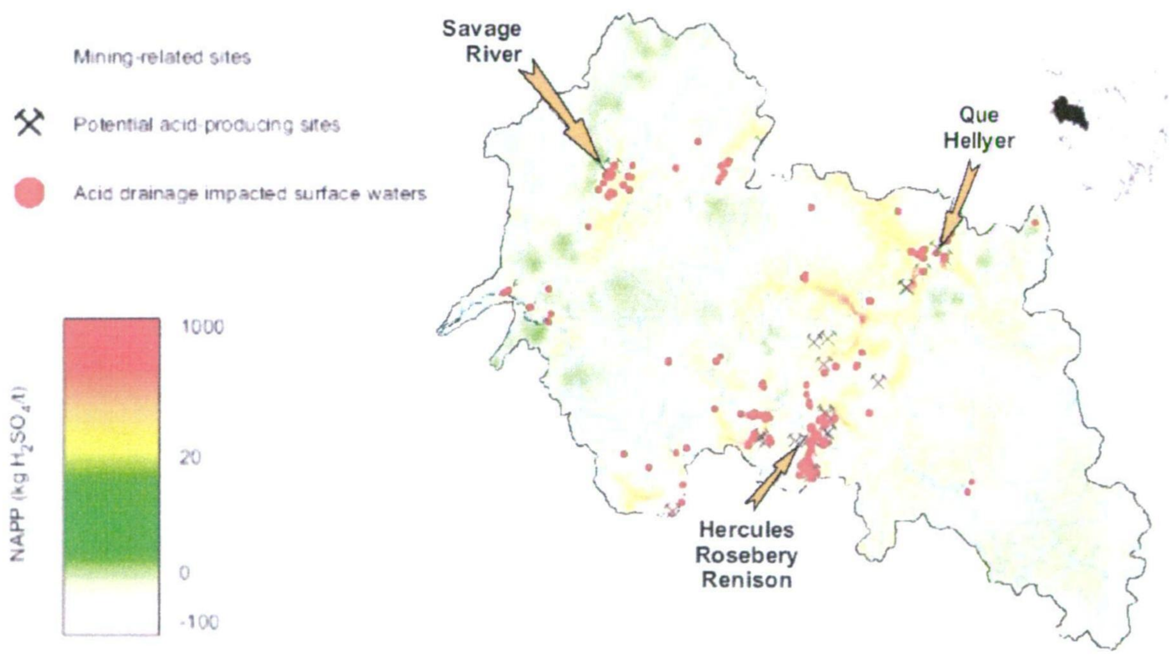


Figure 3-2: a) Extract of acid mine drainage map[8]

3.5 The Use of GIS for EIA in Mining

The use made of GIS in mining ranges from landform modelling (Boggs, Evans et al. 2000) to minesite rehabilitation (Devonport, Riley et al. 1992, Hannan 1995). Best standard practice examples in mining include landform design and waste rock

[8] Gurung 2001, page 17

modelling (Environment Australia 1997). Riley (1992) states that GIS has the potential to become part of an overall planning and management system. Reasons for limited use to date are cost and lack of GIS expertise, need for access to spatial data and analysis tools, and the availability of ready-to-use models (Haklay 2000, Green 1999). While cost and the need of expertise are likely to be reduced further in the future due to an increase of low-cost, user-friendly desktop GIS packages, access to spatial data and the availability of specialised models are more critical to the successful use of GIS in EIA.

EIA in mining involves many environmental aspects. A GIS suited to EIA in mining needs to combine all relevant environmental aspects and to simulate impacts caused by different mining operations at various mining stages. Such a GIS system requires advanced modelling capacities and the ability for analysis for prediction of outcomes to support decision-making. As an overall management system a GIS-based EMS could combine:

a) A large data storage for spatial and non-spatial information

b) Spatial analysis and environmental modelling combined with an expert system for decision support

c) Integration in environmental management

Data Collection and Storage

A mining project must comply with a range of legislations and best practice standards. A large amount of spatial and non-spatial data and information is necessary for an EIA process. The database needs to store spatial and non-spatial information, for example "shape" files, aerial photos, text documents or tables. Currently data for an EIA in Tasmania are collected from various sources such as The LIST, DPIWE, MRT etc. For spatial analysis in EIA, high quality digital spatial data is needed. For example, to identify the best location and design for waste dumps, a scale of 1:1 000 or larger is most suitable. In Tasmania, most spatial data are provided by the Land Information System Tasmania (the LIST), which administers the Tasmanian Spatial Data Directory (TSDD), a sub-directory of the Australian Spatial Data Directory (ASDD). These directories can be queried online. A search for the area of Savage River reveals 197 entries of spatial information. Most thematic data layers such as soils are only available and accessible for small scales (1:100,000). This TSDD contains links to several other Australian databases such as the "Environmental Data Directory (Green Pages)" and "Geoscience Australia".

Some spatial data can be downloaded free of charge from the Environment Australia website[9]. The data sets are however not complete for the whole country and data quality varies. For the area of Savage River, the website lists 1455 spatial data entries. Most data layers are not relevant for an EIA outlined here or are too broad for detailed analysis. At present, access to environmental data for EIA is not readily available on governmental websites. Spatial data collected and stored consistently for a long period can be used to show changes over time. For example, data on water quality along the King River combined with data on riparian vegetation shows the re-growth rate of riparian plant communities as a result water quality improvement after rehabilitation of the river previously affected by mining. The EIA process is usually too short to collect such data. As there is not a Tasmanian wide environmental research database, the best information on the current environmental situation is the Tasmanian State of the Environment Report (SDAC 1996). The information provided is however mainly descriptive and therefore difficult to use in EIA. To be useful for EIA, environmental data ideally would be stored systematically and over a long period over time. A developer for example can then use the data available on the King River for impact assessment of a further development at the same stream. In an ideal situation most relevant data needed for EIA, metadata and user guidelines would be readily available free of charge in digital format from the local government responsible for approving a new development. This would reduce time and cost for locating and integrating environmental data, which could instead be invested in collecting more specific data and developing suitable analysis methods for individual environmental impact assessments.

Data is usually collected from various sources (e.g. reports, surveyed field data, aerial photos or satellite images) and exists in many different formats (various GIS, table, text and image formats). For use in GIS, some form of conversion is often needed to make the data compatible with the GIS system. Table 3-1 shows the different types of information and possible conversions for use in GIS.

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[9] www.environment.gov.au

Data type	**Conversion of data for use in GIS**
Descriptive text documents (e.g. reports)	• Translation into spatial data by generating tables, digitising, add to existing GIS files
Tables	• Add Easting and Northing or Longitude and Latitude • Import/ link from database or compatible table format
Data from field collection (e.g. GPS)	• Format conversion • Import in compatible format
Aerial photos and satellite images	• Scanning (from paper photos) • Geo-referencing
Paper maps	• Scanning. • Geo-referencing
GIS layers	• Format conversion between GIS programs (e.g. ESRI, MapInfo, Manifold etc.)

Table 3-1: Data types and conversion into digital spatial data

Data classification

After Data collection and conversion, the next step in the EIA process is classification. Table 3-2 shows three fundamentally different classifications used in environmental planning. By comparing these three classifications it becomes obvious that EIA assessments based on these classification would result in three different statements.

DoE, UK (1989)[10]	Department of Planning, NSW (1985)[11]	SOER (2003)[12]
Physical: • Air and atmosphere • Water resources and water bodies • Soil and geology • Flora and fauna • Human beings • Landscape • Cultural heritage • Climate • Energy *Socio-economic:* • Direct / indirect • Demography • Housing • Local services • Socio-cultural	• Land use • Land form • Visual quality • Drainage pattern • Surface water • Groundwater • Soils/ land stability • Vegetation • Fauna • Air quality • Noise & vibration • Residential population • Employments • Local/ regional economy • Historic / archaeological sites • Road/ transport system • Utilities provision • Service provision	• Atmosphere • Land • Inland water and wetlands • Biodiversity • Settlements • Cultural heritage • Coastal, estuaries and marine

Table 3-2: Different categorisation of components of the environment

From a GIS perspective, categories are layers of information rather than independent categories. This has the advantage that data can be selected and combined as needed. As all developments are different in their impacts on the environment, the classification should be flexible. Instead of a static list of aspects broader linked categories should be used.

Spatial Analysis and Environmental Modelling

GIS allows various analysis methods for EIA needs. These range from digitising features from aerial photos or other information to sophisticated simulations. Some queries such as for identifying the seven matters of national environmental

[10] Department of Environment (UK) (1989) in Glasson et al (1994), p.17. Environmental assessment: A guide to the procedures.

[11] Department of planning, New South Wales, in Aplin, 2002, p. 219.

[12] State of the Environment Report (Resource Planning and Development Commission, Tasmania, 2003)

significance outlined in the EPBC Act 1999 (see Sec. 3.1) can be carried out on the Environment Australia Website (see Figure 3-3).

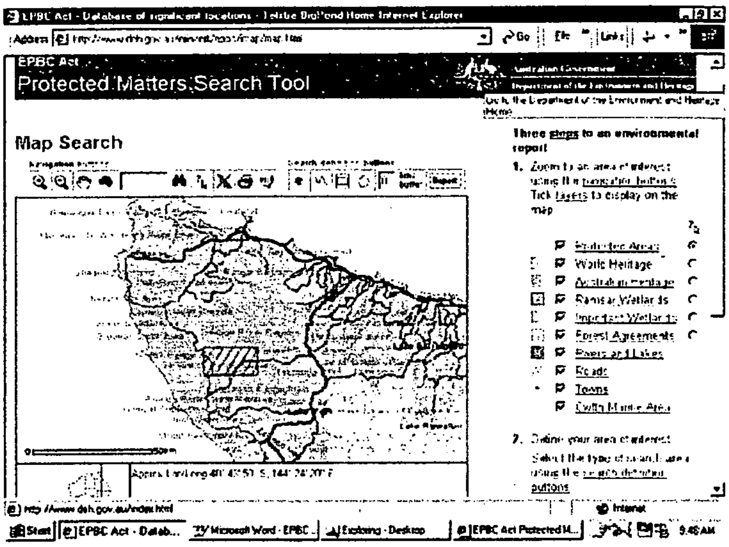


Figure 3-3: Web-enabled EPBC search tool[13]

The prediction of impacts can result in the need for complex specific models, which as Morris (1996) states:

- are not always readily available
- are time consuming to develop
- require detailed data, to be of practical use
- can fail if too complex

One major benefit of modelling in GIS or integrating model results is the capacity of spatial visualisation, which increases the understanding of relationships and cumulative impacts for non-GIS experts and non-scientists (Slawecki, dePinto et al. 2000). While integrated modelling capacities are increasingly available in GIS packages (3D, geostatistics), spatial visualisation is increasingly utilised by non-GIS programs. The latest version of Matlab for example includes a "map tools box", with traditional GIS functions such as spatial buffers and overlays (Matlab ref).

The integration of environmental models for GIS-based EIA could be used for more sophisticated impact simulations. Using the example of the King River, such a

[13] Department for Environment and Heritage (DEH) 2004, www.deh.gov.au/erin/ert/epbc/imap/map.html

simulation would show the effects of a development near the river based on changes of the current conditions. For a planned mining project, a simulation model could be used to changes in the water quality (e.g. water flow, temperature, nutrients) based on the input of information such as how much water will be used and how much and what type of discharge the mine will produce. Another example is a 3D landscape model, which could be used as a prediction tool to prevent unpredicted, strong visual changes in the landscape. A developer would need to enter indicators such as the position and shape of the mine, area of vegetation clearance and planned infrastructure. The model as an automated process could simulate the visual effects of the planned mine development based on indicators such as the loss of vegetation (e.g. using a current TASVEG layer in combination with aerial photos or high-resolution satellite images), visibility and prominence (e.g. calculated from slope, aspect and viewpoints using a DEM); and existing natural pattern and built forms (e.g. from aerial photos or high-resolution satellite images). The analysis results would show aspects such as the acceptable amount of vegetation clearance and the best location and shapes for mine infrastructure according to visibility and the character of the surrounding area.

Environmental Management System (EMS)

Cashmore (2004) argues that the existing emphasis on process and procedures in EIA fails to develop a more holistic and integrated approach. This could be overcome by integrating EIA together with monitoring and auditing in one GIS-based EMS. Thus GIS can develop into a decision support tool for longterm environmental planning and management for the lifespan of the project. As shown in the previous section, most assessments need spatial information and can be undertaken with spatial analysis tools in GIS. Updating and adding new GIS tools, as they become available, ensures continuous improvement of assessments (see 3.5).

A recently added component in EMS is "environmental communication", which endeavours to make the system transparent and understandable for anyone. Spatial visualisation of assessment results is part of the general GIS process. This allows outcomes of complex models to be displayed and easily judged. For example, by using a hydrological model, the degree of pollution of a stream can be shown with colour gradients. The location and area can be assessed immediately on the computer screen and a map printed. This quick check would otherwise require interpretation of tables and graphs. Thus spatial visualisation is an important element for transparency and communication. Another aspect of environmental communication is documentation of data and processes employed. Although various attempts have been made to store metadata in GIS, no common solution has been found (Goodchild and Zhou 2003). Some GIS packages allow flow charts to be stored with the GIS model. However these can easily be generated using available tools in text or graphic programs.

3.6 Conclusions

GIS is a widely used tool for spatial analysis in various fields ranging from mapping threatened species to hydrological modelling (Feng 2000; Busby 2002). However, its use in environmental impact assessment for mining has not been fully explored to date. The main reasons, why the use of GIS for EIA for mining is limited are the lack of sufficiently detailed data and simulation tools. In this chapter it has been suggested that GIS can take the role of an expert system by use of impact simulation tools and outcome analysis for EIA. These can be integrated into ongoing environmental management, once the project has been approved. Such a GIS-based environmental management system could bridge the current gap between a static EIA document and a more dynamic and interrelated process. Better access to environmental data, integration of environmental models into GIS and capacity for analysis of outcomes have been identified as essential elements for such a system. This chapter provided an overview of GIS and EIA. In the next chapter a theoretical framework will be developed for the use of GIS in mining.

PART B: CASE STUDY

A THEORETICAL GIS-BASED EIA FRAMEWORK FOR THE SAVAGE RIVER IRON-ORE MINE

CHAPTER 4 INTRODUCTION

4.1 Background to the case study and outline

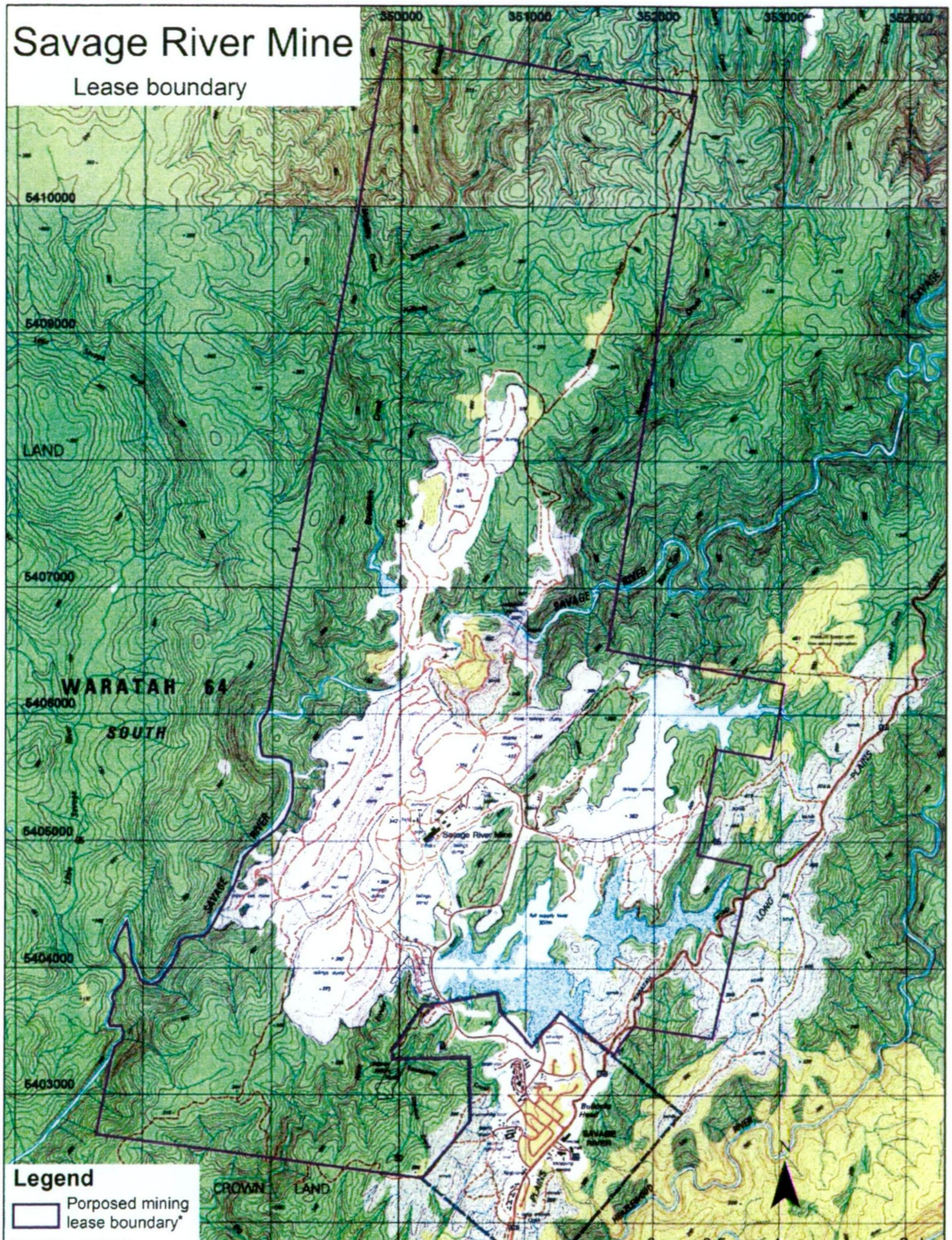
In Part A, the use of GIS for EIA with a focus on mining has been reviewed. In Part B, a theoretical framework for an EIA in mining is developed using GIS. Savage River mine is an ideal example to demonstrate the strength of the use of a GIS in a complex EIA process. Mining at Savage River has affected the environment in the past and re-developments will need a more strategic and integrated approach to achieve an improved, up-to-date environmental standard. For extension of the mine an EIA needs to utilise modern principles and technology in order to take into account additional aspects including historic pollution and current rehabilitation programs. GIS provides the capacity for integrative analysis of diverse data for decision support. The objective of this case study is to develop a conceptual GIS-framework for an EIA process. The case study is structured in three parts: Chapter 6 focuses on the use of GIS for "screening and scoping", and "public consultation"; Chapter 7 covers "key environmental impact analysis"; and Chapter 8 integrates the EIA outcomes into an environmental management system (EMS). Chapter 8 also provides recommendations for the EIA approval process using GIS and its integration into the planning system in Tasmania. Conclusions and further research requirements are given in Chapter 9.

4.2 The Savage River Mine

The Savage River mine is an open cut iron ore mine, with relatively low concentration magnetite deposits. Mining history can be traced back to the 1880, however serious exploration started in the 1950 when mining technology was sufficiently advanced. Open cut mining operation started in 1967. Under the Planning Scheme 1993, the mine site and surrounding area was zoned as "rural". In 1996, the township of Savage River had a population of 156 inhabitants. The mine is situated in a relative remote location in the northwest of Tasmania in the Waratah–Wynyard Municipality. The next major town is Burnie on the Northwest Coast, ca. 100 km to the north. The mine lease of 2,380 ha is mainly on unallocated Crown Land and comprises of a similar area to that of the previous operator (see Figure 4-1).

The mine lies in a region of dense rainforest. To the north and northeast of the mine is the Savage River Recommended Area for Protection (RAP). Land use in the region is characterised by mineral exploration, nature conservation, and is important for bushwalking, rafting, boating, fishing, photography and off road vehicle driving.

The impact of previous mining was described in the DPEMP as extensive, including the "degraded nature of the receiving waters downstream of the mine site" (ABM 1996, p.ix). The new mine operation was expected to result in a "slight increase in the total amount of land disturbed by mining" (ABM 1996, p.32). The total pit area is estimated to expand from 153 to 163ha and the total waste dump area from 303 to 393ha. The environmental management procedures implemented by ABM were expected to cause little additional impacts and to be compatible with current land uses (ABM1996).



*Estimated from maps provided in DPEMP 1996

(Co-ordinate datum AGD 1966)

Figure 4-1: Topographic maps and proposed mining lease boundary

4.3 The EIA Process

4.3.1 Introduction

As described in Chapter 3, EIA in mining, particularly for re-development of mines, differs from other common EIA assessments as mines:

- Operate for a limited period of time and activities eventually cease
- Cover extensive areas
- Involve diverse aspects of the environment, which result in interrelated and cumulative impacts
- Often have a potential to produce highly concentrated and toxic pollutants
- Need to consider existing impacts from previous mining activities
- Are often in remote areas surrounded by natural environment with high conservation status
- Affect socio-economic situation of the remote region

These characteristics result in a unique EIA process for mining, which in addition often include special agreements (e.g. Goldamere Agreement) and co-operative approaches between the mine operator and environmental agencies for rehabilitation of past effects.

4.3.2 The Goldamere Agreement

Similar to the Mount Lyell situation, where a specific Act of Parliament was established to allow for renewed mining, the DPEMP at Savage River was modified by the *Goldamere Pty Ltd Act 1996* (GPLA). The GPLA addressed the responsibility for pollution from previous mining. It affected the EIA by recognising that:

> *"it is presently impossible or impractical on the existing information to accurately predict the nature or extent of future environmental impacts resulting from pre-existing pollution and contamination and unrehabilitated land".* (Goldamere Pty Ltd [Agreement] Act 1996 [6.1])

Therefore no consideration was made in the original EIA process for integrating ongoing effects of past mining into future environmental management for the mine re-development (extension).

4.3.3 The EIA process

In 1996 Goldamere Pty. Ltd., trading as Australian Bulk Minerals (ABM), made an application to the local Planning authority (Waratah-Wynard Council) for re-development of the iron-ore mine at Savage River (ABM, 1996). The re-opening of the mine mine was considered a Level 2 development project under LUPAA 1993 and a Development Proposal and Environmental Management Plan (DPEMP) was required by the Environmental Management and Pollution Control Act 1994 (EMPCA). In comparison, the renewal of the mining operation at Mount Lyell was classified Level 3 (State significance) and needed a Social, Economic and Community Impact Statement (SECIS).

The DPEMP for Savage River was referred to the Board of Environmental Management and Pollution Control (the Board) in the Department for Environment and Land Management (DELM) as the authority to assess the EIA and placed on public display. DELM prepared a report including comments of the public, which was assessed by the Board. It finally decided to grant a permit for re-development of the Savage River mine (ABM, 1996).

4.3.4 Spatial Data Requirements by DELM

The DPEMP at Savage River needs to provide spatial information for certain existing and planned features. At a scale of 1:25,000 information must show:

- Land tenure;
- Topography and hydrology;
- Access routes;
- Locations of waste disposal areas,
- Boundaries of the mine lease and
- Location of excavations.

At the scale of 1:5,000 a mining plan must show

- Likely environmental impacts
- Existing or planned mining structures (pits, waste rock dumps etc.)
- Areas of existing and planned vegetation clearance
- Significant infrastructure (roads, crushing plant, pipelines etc.)
- Locations of temporary and permanent stockpiles, raw materials, topsoils etc.
- Transport routes

- Residential premises
- Location of the proposed signage

4.3.5 The Savage River Rehabilitation Program

The EIA process at Savage River needs to consider ongoing rehabilitation, which adds to the complexity. The EIA In 2001 DPIWE started the Savage River Rehabilitation Program (SRRP). This project was funded with 24 million AUD (approximately one half is provided by the State and the other half by ABM). The aim was to bring all research together and to develop innovative rehabilitation techniques and remediation options for ongoing mining (DPIWE 2001). The SRRP is a co-operative project between DPIWE and ABM and influences environmental management and rehabilitation in that results will be progressively implemented the EMP as shown by the graphic in Figure 4-2.

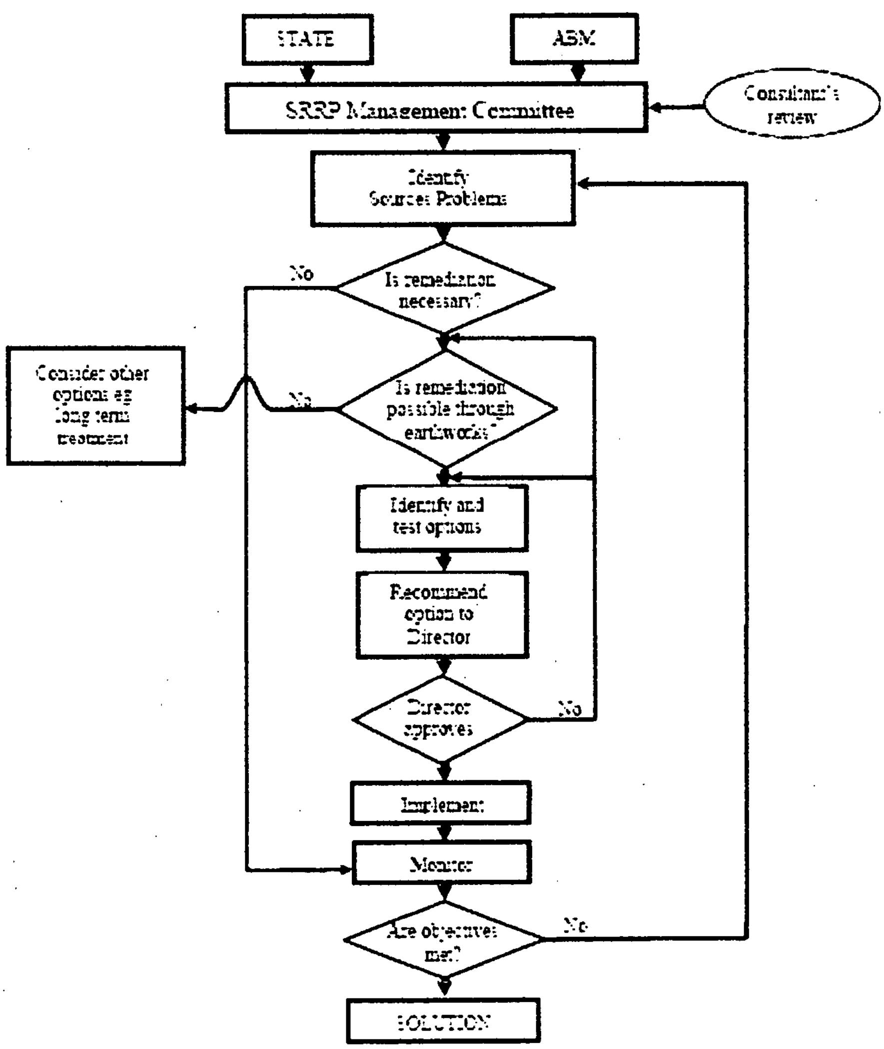


Figure 4-2: Remediation at Savage River under the SRRP program (DPIWE 2001)

4.4 Discussion

The information required by DELM (now DPIWE) is limited to geographical locations of existing and planned mine infrastructure. This would not necessarily require the use of GIS. Paper maps could be used instead. Apart from showing locations, GIS can be used to predict impacts caused by the re-development of the mine using spatial analysis tools and integration of all components of the EIA process.

The current DEMP lacks a clear separation between the EIA and EMS component. A "level 2" project under LUPAA needs to provide a DPEMP, i.e. a combined development proposal and environmental management plan, using specific guidelines provided by the Board (ABM 1996). Compared to a normal EIA, the DPEMP allows for consideration of environmental management during the EIA process. Harvey (1998) argues that the monitoring and review components in the DPEMP for the Mt Lyell mining re-development project strengthened the EIA outcome. However, the DPEMP can result in a mix-up of EIA and environmental management strategies if both components are not clearly separated. For example rehabilitation strategies are outlined for flora and fauna without an impact analysis. In this case the actual impacts by mining remain unclear and cannot be adequately considered by the Board for approval.

The Savage River has a long history of mining. In order to predict impacts of the new development, a clear understanding of historic pollution is needed. Information of historic pollution of Savage River predates computer technology and environmental legislation. Also, the mine has changed ownership several times. Information on impacts by historic mining is therefore scarce and difficult to collect. Aerial photos, descriptions and manual records managed by the current owner are possible data sources (pers Comm. Daniel Ray, DPIWE, 2004). These need to be converted for use in GIS. This is time consuming and costly. Appropriate timeframe and resources need to be allocated and methods established at the scoping stage of the EIA.

GIS provides provides a range of tools from elementary display to complex analysis of spatial data (see Figure 4-3), which can be used to make EIA an effective instrument in environmental planning.

Baseline data storage and display of locations and features

↓

Digitising and storage of specific features or areas

↓

Basic measurements (distance. area)

↓

Classification. reclassification of features

↓

Overlays

↓

3D modelling (volume. slope. aspect. visibility)

↓

Environmental modelling and predictions including various scenarios (links to other scientific models or integrating models using programming software)

↓

Remote data entry for monitoring

↓

Customisation and links with multimedia for presentation and public participation

↓

Web-enabling for remote access of information

Figure 4-3: GIS tools for use in EIA from simple to sophisticated

In the following chapter the use of GIS is analysed for the different stages of an EIA.

4.5 Conclusions

Today's understanding of the interrelatedness of ecological process requires a modern and strategic approach in EIA. Modern environmental assessments need to adequately and accurately address diverse range of aspects to model and predict medium and long-term effects. GIS is ideally suited as it provides a range of analysis tools to cater for a modern and integrated approach in EIA. For the EIA at Savage

River two aspects are important. First, consider historic pollution from mining and secondly, integrate the EIA outcome in future environmental management.

CHAPTER 5 GIS FOR SCREENING AND SCOPING

5.1 Introduction

The first stage of an EIA is "Screening". This determines whether the development project needs an EIA (Glasson 1992; Harvey 1998, see also Chapter 3). As apparent by current issues occurring from previous mining operations, mining at Savage River causes significant environmental impacts and therefore requires an EIA. In the scoping stage, all available spatial and non-spatial data in digital or printed format are collected. The scoping process includes the description of the location, history of the mine, the current environmental situation and the proposed development.

5.2 Data requirements and collection

The scoping stage requires a range of spatial datasets. It is useful to consider the needs of data for later key environmental impact assessment. For example to show the topography of the area surrounding the mine a DEM of 1:25,000 would be sufficient. However for slope stability analysis at the key impact stage, the resolution needs to be 1:10,000 and higher.

At the scoping stage, format, scale, accuracy and currency of data needed for the following stage can be defined. The data can be grouped into:

- Base data (e.g. roads, locations, drainage, boundaries etc)
- Proposed mining (mine structures, facilities, township)
- Digital terrain data (DEM, TIN or ALS)
- Environmental data (e.g. geology, vegetation, habitat, soils, visual landscape)
- Statistical data (socio-economic, cultural)
- Aerial photos / Satellite images
- Monitoring data / data from field inspections

João (2002) distinguishes between three effects for EIA due to scale and accuracy: number of features, size (length, width and area) and position. The change of detail from one map scale to the next is a result of generalisation (Hake and Gruenreich 1994). The sequence displayed in Appendix 2 illustrates the loss of detail from a 1:5,000 to 1:100,000 map scale. Goodchild (1996) provides an overview of accuracy recommended for different map scales (see Table 5-1).

Positional accuracy	Commonly used source of well defined features (U.S.)
1cm	Geodetic control network
1m	Fixed monuments
10m	1:24,000 topographic mapping
100m	1:250,000 topographic mapping
1km	1:2,000,000 topographic mapping, Landsat
10km	AVHRR

Table 5-1: Levels of accuracy (source: Goodchild 1996)

The 1:25,000 "TASVEG" map by the Nature Conservation Branch in DPIWE has an accuracy of 15m (see metadata in ASDD). While this scale is accurate enough to reveal existing vegetation and other features in the area, it is too broad to determine exact boundaries of vegetation communities or to design habitat corridors. Where the exact location is vital, as for example to identify the occurrence of threatened species within the mine lease area or the location of sample data, field inspection (using GPS) would be required in addition to maps based on database queries (Cultural heritage by DEH and "GT SPOT by DPIWE), This is because databases often combine different collection methods and accuracies (see metadata of these databases). More accurate data capture would be part of the key environmental impact assessment stage. The scoping stage is therefore also the stage where the need for additional more accurate data for detailed analysis is identified.

Beside the EIA stage the need for accuracy depends on the relevance of the data. Features within or close to proposed mine structures should be displayed in a large map scale (1:10,000), while features such as settlements and roads (outside the mine lease area) have mainly orientational and overview functions, for which a scale of 1:50,000 should be sufficient. For more general information such as climate or demography a scale of 1:500,000 is normally satisfactory. On the other hand, the location of on-site weather stations for local weather conditions needs a higher accuracy. This can also be used to check for suitability and need for further stations. Table 5-2 gives an overview of recommended data and map scales for the scoping stage in EIA. A 1:25,000 map scale is generally suitable for base maps and considered a good starting point for inventory assessment (Hake and Gruenreich 1994; McCullum 2004).

Data type	Recommended Map Scale	Anticipated Source
Coastline	1:100,000	DPIWE
Planning scheme (Waratah-Wynyard)	1:100,000	Municipality
Roads	1:50,000	DPIWE
Settlements	1:50,000	DPIWE
Mine lease boundary	1:25,000, 1:5,000	MRT
Geology	1:25,000	MRT
Proposed mine structures and facilities	1:25,000, 1:5,000	New mine operator
Topography (DEM, TIN, ALS)	1:25,000, 1:10,000	DPIWE, Forestry Tasmania, MRT
Savage River township	1:5,000	Previous mine operator
Landscape character types	1:250,000	Forestry Tasmania
Climate (precipitation, temperature, evapotranspiration)	1:2,000,000	Bureau of Meteorology
Weather stations	1:25,000,	Bureau of Meteorology, previous mine operator
Hydrology	1:25,000, 1:10,000	DPIWE
Stream classes	1:25,000	FPB
Groundwater	1:100,000	DPIWE
Existing and new sample sites	1:25,000	Previous mine operator, DPIWE
Fauna (habitat)	1:25,000	DPIWE, FPB
Flora (vegetation communities)	1:25,000, 1:10,000	DPIWE, FPB
Threatened Species	1:25,000	DPIWE,
Conservation areas and status	1:25,000	DPIWE
Soils	1:25,000, 1:10,000	DPIWE, FPB
Cultural Heritage	1:25,000, 1:10,000	DEH,
Tourism and recreation facilities	1:25,000	Tourism Tasmania
Socio-economic data	1:500,000	ABS, Municipality
Land tenure	1:25,000	DPIWE
Location of surveys in the area	1:50,000	Various
Orthophotographs	1:10,000	DPIWE
Satellite imagery	1:25,000	DPIWE/ DEH

Table 5-2: Recommended datasets, scales and sources for the scoping stage in EIA

Data Collection

A search using the Tasmanian Spatial Data Directory (TSDD) is the first stage. This reveals that most of the datasets listed in Table 5-2 are not available in the recommended scale. Specific information such as river health, riparian vegetation and ecological landscapes exist often only in patchy coverage from individual surveys or at a broad scale. A list of available data from national and state-wide environmental surveys can be found on the website of Environmental Resources Information Network (ERIN 2004) or ASDD. In the absence of large-scale digital datasets and maps, original data sources (aerial photography, data collection) would be necessary at this stage, as is likely to be the case for remote areas. Time and cost in assembling this map data need to be considered in the overall EIA planning.

Most of the data required for socio-economic and cultural impacts are acquired from census information collected and published by the ABS. Data is published every 5 years for different spatial units. The smallest census unit is the collection district and the last census year was 2001. When comparing or combining data from different census years, possible change to census unit boundaries and collection methods needs to be considered (ABS 2004). More detailed statistics on mining may be provided by MRT. The Municipality may also provide specific data for the region. Data on cultural and archaeological data may be obtained from governmental agencies (e.g. DPIWE).

Some information is not available as spatial data ready for input in GIS. Data preparation and conversion into GIS formats is needed and some of this is done at this stage, for example, georeferencing of scanned map originals and digitising of current and planned feature/ area boundaries (see Chapter 2).

5.3 Data storage

In GIS, the database management system (DBMS) is the key driving force (Worboys 1999). It is essential to develop a well thought out database structure at the beginning of an EIA project, as this ensures efficient access to data used in GIS and reduces duplication and the need for transfer of data. A centralised database is a common approach in GIS. It has the capacity for data files to be accessed from different locations. Data structure in the database needs to be flexible enough to allow changes to be made during the EIA process. For example, the number of categories or the data within each category may be expanded.

5.4 GIS for the Scoping Stage

5.4.1 Location

The first step in the scoping process is to show the mine location in GIS. The advantage of GIS compared to traditional paper maps is that GIS information is more up to date than printed maps. The 1:25,000 series map sheet "Savage River" was published in 1987 and does not show all existing roads and other recent features. Another advantage is that the area of interest can be chosen specifically without being restricted to map boundaries and scale. The disadvantage is that digital data may not provide the same amount of detail. A combination of both methods is preferable. The mine lease boundary can be imported from cadastrial data. To show the geographical location of the mine and surrounding features geo-referenced paper maps and orthophotos provide adequate detail. For later impact analysis, information including hydrology, settlements and vegetation are needed as GIS layers. Table 5-3 shows possible questions concerning the location of the mine.

Theme	Possible questions in GIS
Location	• Where is the Savage River mine in Tasmania and in respect to other mines on the West Coast? In which municipality does is lie? • What roads are used for access? • Where is Savage River in respect to other settlements? • Where is the next larger town?
Topography	• What is the terrain like? • How is the mine situated in respect to the Savage River and the various surrounding catchment?
Mining	• Where is Savage River in respect to other mines on the West Coast? • What is the significance of Savage River compared to other mines?

Table 5-3: Possible spatial questions about locations

5.4.2 Mining history

On a broader map scale (e.g. 1:100,000), the mine area at Savage River may be displayed along with other existing mine sites, geology and lithology of the West coast. This would show its significance and respect to other mines on the West coast and associated geological structures. The 3D model developed by MRT and the University of Tasmania (CODES) can be used to display additional geophysical properties (CODES 2003). Mining development based on historic data could be shown by a sequence of maps displaying different stages of development at Savage

River. The integration of mining history data in the scoping stage of the EIA is important as it shows locations and possible reasons for historic pollution (ore stockpiles, waste dumps, sewage) and helps in planning of mitigation measures for the planned mining operations. Aspects about the past mining activities that can be best illustrated in GIS are listed in the table below.

Theme	Possible questions in GIS
Ore body	• What was the original size, shape and location of the ore body underground and what remains today?
Mining	• What did the various stages of mining remove and when did these occur?
Infrastructure	• Where were roads, hauls and pipelines from previous mining operations and how have these evolved or been replaced? • Where is the mining township, how can it be accessed and what infrastructure exist from previous mining stages and times? • What is the condition of the infrastructure?

Table 5-4: Possible spatial questions about the mining operation

GIS may also be combined with outputs from dedicated mining software used for modelling and calculation of ore bodies. Up-to-date spatial information of the mine could be provided as remotely sensed imagery. Beside maps, text documents and photos (new and historic) may be stored in the same database for analysis and display. The size of previous pits and waste dumps, oxidation periods and known disturbances, as shown in these historic documents, can be used in key impact analysis to assist in prediction and management of AMD for future mining activities.

5.4.3 Proposed development

In this category, information of all available and planned infrastructure, mines structures and facilities would be collected. This includes 3D data to visualise height, depth, slope, aspect and volumes of mine structures. Data used for planning of mine operation (i.e. ore extraction) might be imported from other software (CAD, laser image processing software) as this may deliver more accurate data than derived from a ready available DEM. It would later be especially beneficial for detailed spatial analysis (e.g. calculation of waste material, design of waste dumps). The table below summarises questions concerning the proposed development.

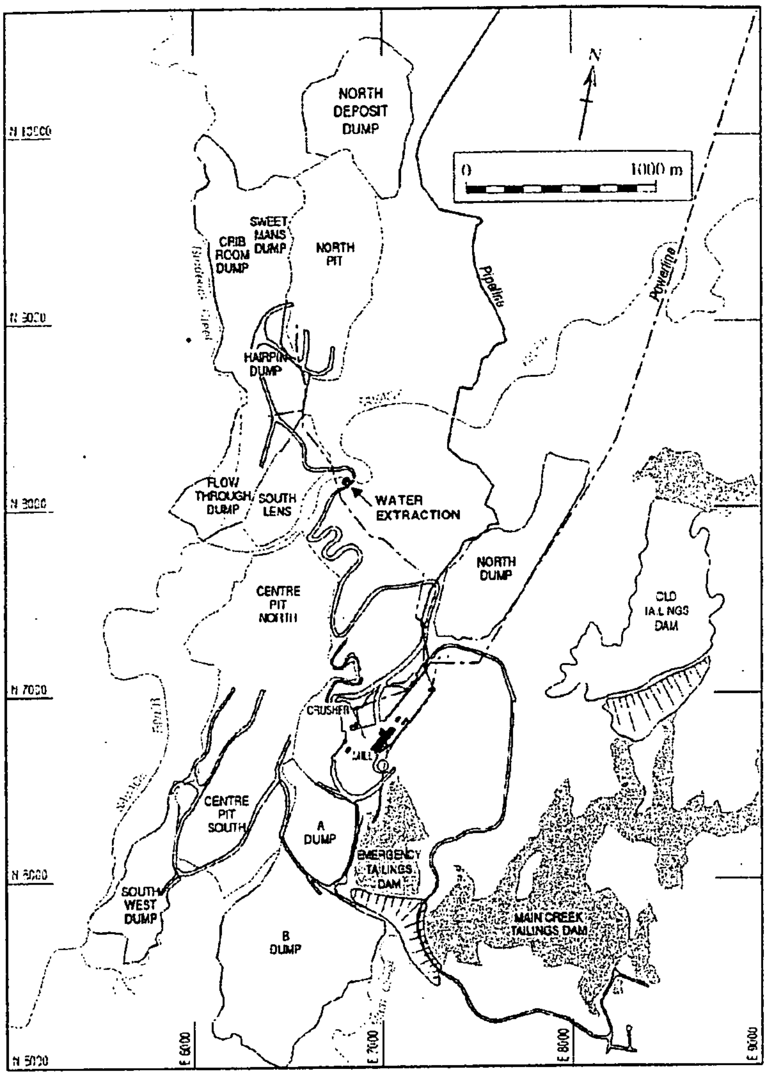


Figure 5-1: Existing mine structures at Savage River (Source: ABM 1996, p. 4)

Theme	Possible questions in GIS
Mining operation	• Where will mining occur, what type and when? • How and from where is the ore accessed?
Mining infrastructure	• What will change and where (size and shapes of pits and waste dumps)? • What will the changes be in respect to the existing mine area? • Which new infrastructure (hauls, roads, buildings, processing equipments) will be needed and where?
Township	• Will the township need to be changed or upgraded and how? • What new facilities will be required?

Table 5-5: Possible spatial questions about the proposed mining extension

5.4.4 Current environmental situation

The existing environmental situation should be the major emphasis in the scoping stage, which apart from protection of flora and fauna, determines the value for the region and postmining land use potential. A range of issues, which could be mapped in GIS are listed in Table 5-6.

In a first step available databases (e.g. DPIWE, FPB, DEH, MRT etc.) could be queried. Figure 5-3 shows a screen print of the "TASVEG" database provided by DPIWE. This would reveal that Savage River is surrounded by 'short' and 'tall rainforest'. Next, rare and endangered species could be detected in the GT Spot database also provided by DPIWE. The "GT Spot" database for threatened species contains data from different collections and times and is therefore not consistent. Also, the collection contains single entries rather than state-wide surveys. Thus, information needs to be considered with caution, especially with animals that are believed to be extinct (see query result in Figure 5-4). It is therefore essential to analyse the report as well.

Figure 5-2 : Landsat 7 image[14]

[14] UTAS

Theme	Possible questions
Pollution	• What are the current types of pollution and where do they occur? • What is the geographical extent of the current pollution? • To what extent will this be reduced or affected by due to new mining practices?
Health and safety	• Where are risks for pollution of drinking water and air quality of the area? • How far away are potential sources of pollution from settlements and recreational areas (e.g. fishing, recreation)? • Where will the water quality be monitored? • Where are risks of land instability, flooding, erosion and siltation in the current landform?
Flora and fauna (terrestrial and aquatic)	• What flora and fauna exist in the area? • Where and how much has mining already affected flora and fauna?
Landform	• Where has the landform been changed due to previous mining? • Where are waste dumps, pits, dams etc.?
Landscape	• Where can mining be seen outside the operational zone? • How will the landscape change due to mining extension over time? • What will the final landscape look like? • What are the effects on the overall character of the surrounding landscape? • What is the effect on the viewing public?
Rehabilitation	• Where and how will rehabilitation be undertaken? • What is the hydrological situation especially the flow of waste or treated water?

Table 5-6: Possible spatial questions about environmental issues

The databases give good indication of relevant data layers that will need to be collected. From these data layers, a draft map would be produced to display the environmental issues in more detail. The advantage of map compilation in GIS is that basic locational information such as roads and mine lease area and proposed mine structures could be displayed easily on each map. Also, boundaries of existing conservation areas and recommended areas of protection may be included, as these give an indication of rare flora and fauna. In the next step, information layers could be combined to give relational meaning, for example vegetation maps could be combined with recorded locations of endangered species.

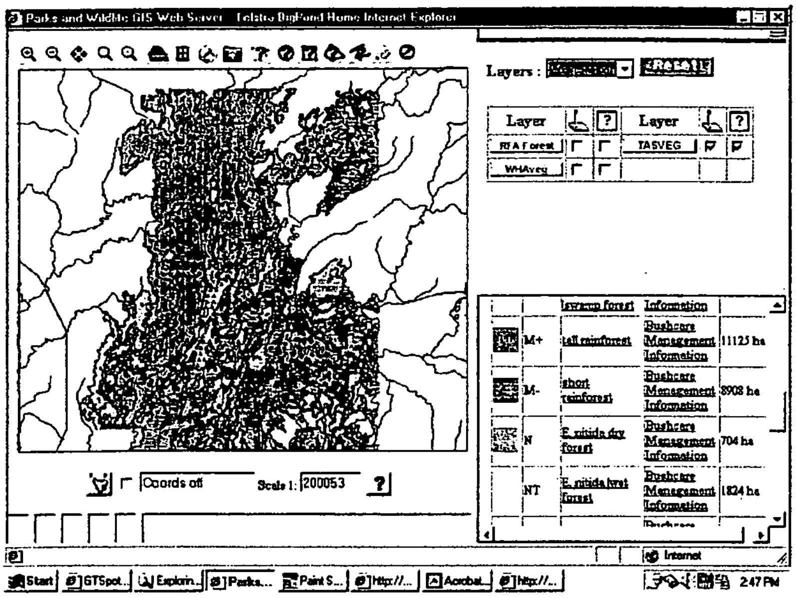


Figure 5-3: Example for a query of the TASVEG database (DPIWE)

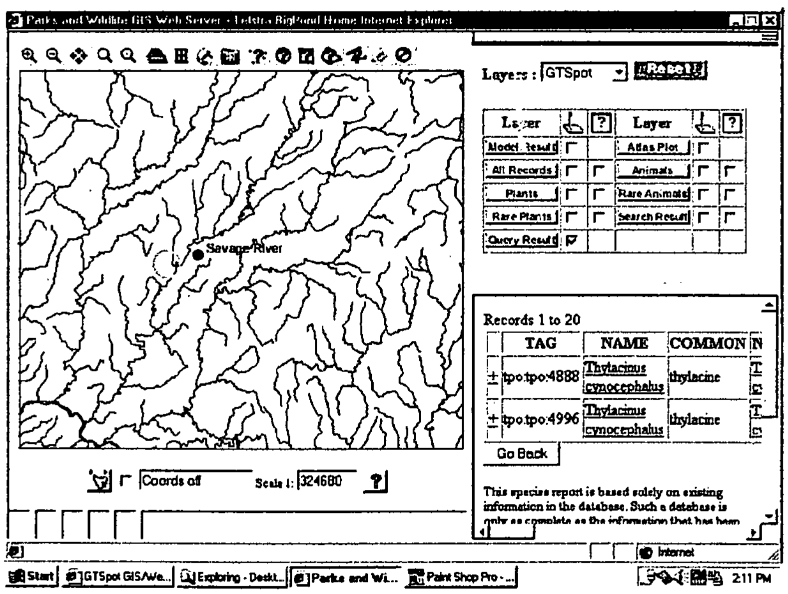


Figure 5-4: Example for a query in the GT Spot database (DPIWE)

Figure 5-4 shows two draft maps using consistent base information. For more detailed queries, these separate data layers can then be combined (using e.g. overlay functions) and a query in the combined attribute tables performed.

5.4.5 Current socio-economic situation

Demographic data as collected by Australian Bureau of Statistics (ABS) could be imported into the GIS to gain information about population sizes of Savage River and surrounding settlements, population characteristics and migration rates. The socio-economic situation can be determined by using existing maps based on statistical data or by creating specific maps for the regions using statistical data such as economy and employment rates (see also Table 5-7).

Theme	Possible questions
Socio-economic situation	• What is the population of Savage River and the surrounding settlements? • What are the population characteristics (gender, age, education)? • What is the employment situation (employment type, number of employees, permanent / casual, unemployment rate)? • Are there enough skilled workers for the mine? • Is there enough accommodation for workers? • Are there recreation facilities in the area of the mine? What is the scale of use? • Where are opportunities for expansion of mine and community services and facilities? • From where can the mine be accessed during operation (viewpoints, interpretation)?
Cultural aspects	• Do Aboriginal or European cultural sites or items exist in the area of proposed mining extension?

Table 5-7: Possible spatial questions for economic and cultural aspects

GIS has the capacity to do viewshed analysis and to generate 3D views based on the DEM to display virtual landscapes. These could be created using other more sophisticated or dedicated compatible graphic and simulation programs (e.g. *Visual Nature Studio*) and imported into the GIS-database.

Beside analysis by GIS, other methods for determining social values and concerns could be used in the scoping phase. These include working with the community of the region and various techniques such as "mental maps", sketches and photographs (Al-Komady 1999). Mental maps may be used, to gain a better understanding of the significance of the mine and the surrounding region to people by their estimation of its size and location (Goodey 1996; Al-Komady 2001; Gertman 2002; Turner 2003). The significance may change in respect to the distance people live away from the mine. People close to Queenstown may give Savage River a lower significance rating due to the much larger mine at Queenstown. While people in Burnie may not be aware of the mine as they may associate and be more familiar with the north and north-east coast rather than further inland. This also depends on their experience of the area. Bush walkers and visitors to the region may have seen the mine from a higher vantage points and gained an impression of its location and size, whereas others may know the mine only from the media or through discussions with others. 3D views and virtual landscape graphics require detailed data, which may not be available at this stage. So instead, using graphic programs sketches could be drawn and photo-collages developed manually. These results could be imported for the database in GIS and linked as pop-ups to certain locations (e.g. viewpoints).

5.5 Public consultation

5.5.1 Spatial information in the development proposal

Ideally, the EIA presentation of the development proposal will include all possible environmental impacts and mitigation measures. These will then be addressed or dismissed during the consultation period. Best practice standards in mining recommend to involve the public in an early stage of mine planning (EPA Environment Protection Agency (EPA) 1995 f; 1995 g). This demonstrates the awareness of the developer about potential issues and possible mitigation needs and control measures. Other issues may be added due to expert or local knowledge gained from discussion. At this stage, environmental impacts are considered at a broad level. In-depth analysis is carried out in the next step for key aspects, which are determined during this consultation period. The presentation could use a range of prepared spatial information in different formats (single and overlaid digital data layers, models and prepared maps). The different types of spatial information and media for presentation are discussed below.

5.5.2 Presentation types

Presentation of the development proposal to the public could take several forms including public hearings, Internet presentation, documentation on CD-ROM and printed documents. For all publication types, different media (text, maps, images, animation, video, sound) could be used. In public hearings prepared maps as well as individual map layers could be displayed depending on issues rising during discussions. GIS combined with multimedia can enhance communication and consensus-building (Shiffer 1999). This is especially the case with advanced visualisation techniques and increasing interoperability between computer programs (Sondheim, Gardels et al. 1999). The combination of GIS and multimedia has been successfully used during public meetings (Shiffer 1999; Al-Komady 2001). The development of these applications is however costly and time consuming at the moment as customisation or additional software is needed (Maguire 1999). More sophisticated customisation may therefore be used for the final presentation of the

EIA or as part of the environmental management system, after approval of the project (see also 7.2.4 for more details). In the scoping process, multimedia GIS could show: the location and size of the mine using links to photos; the development stages and progressive rehabilitation by preparing an animated map sequence; environmental and socio-economic aspects of the area using photos and diagrams; the existing planning zoning of the Municipality linking to the planning scheme. An effective application for public meetings may be a "SketchGIS" which allows immediate integration of ideas and comments and thus overcome the problem of time consuming regeneration of maps or map layers or descriptive notes (Gertman 2002). For transparency and critical review by the audience metadata should be made accessible.

5.5.3 Collection of key issues for in-depth analysis

During discussions with the local planning authority (Waratah-Wynyard Municipality), other governmental agencies (DPIWE) and the public, a range of opportunities and concerns about the environment and the socio-economic aspects are raised; Pros and cons arguments of re-development are collected and alternatives to the currently proposed strategy developed. Concerns could include the following:

- Pollution may threaten drinking water
- Further extension of the mine may affect the important natural values in adjacent conservation areas.
- The pollution may effect fishing
- The wider landscape could be degraded on a long term basis, which has an effect on recreation and tourism in the area
- The mine will be closed earlier than planned due to economical reasons, which will lead to sudden unemployment and
- The mine area cannot be used due to pollution and instability

Some of these concerns may be addressed and overcome by making the mining history, current environmental issues and proposed mining activities more available and transparent to the public. Maps can help as a medium for communication, and also make existing company policies and environmental legislation less abstract, by showing to which specific parts of the mine area they apply and how this relates to the surroundings. During discussions and through other forms of publication, aspects may arise that had not been considered by the mine operator or the planning authority before and these would need to be added for consideration in the analysis. At the same time some concerns by the public may be overcome. As a result of the public consultation period the following list of key concerns and issues, which need further in-depth analysis, may be the following:

- AMD potential
- Other pollution on site
- Impact on public health
- Impacts on flora and fauna
- Impacts on the environment due to hazards such as tailing dam failure or floodings
- Impacts on scenic landscape values
- Local and regional short and long-term employment opportunities or loss and needs for services and subcontractors
- Post-mining land use and development opportunities for the region
- The use of the township after mine closure

5.6 Categorisation of key issues for in depth analysis using GIS

In the next step, existing and new issues need to be categorised for in depth EIA analysis in GIS. As can be shown from previous EIAs, there are several ways of categorising environmental issues. In the last three environmental management plans, including the DPEMP for Savage River, three different unrelated ways of categorisation were used (see Table below).

Final EMP 1996[15]	**DPEMP 1996[16]**	**EMP 2001[17]**
• Water • Air • Flora and fauna • Archaeology and heritage • Visual aspects and landscape	• Archaeology, conservation and heritage • Terrestrial flora and fauna (incl. aquatic) • Soils • Climate • Hydrology • Physiography and topography • Geology	• Cultural and historical values • Local meteorology • Surrounding physical characters • Physiography and topography • Geology • Hydrology • Biological characteristics

Table 5-8: Categorisation of the environment in three different EMPs at Savage River

[15] Last EMP of previous operation

[16] First EMP prepared by new operator (ABM)

[17] Latest EMP by ABM

Existing general categorisations of the environment for EIA can be of help to define categories. However, this can lead to duplication of information and processes in the various categories. For example acid mine drainage involves type of rock, air, water and topography. Categorising by environmental aspects, as suggested in some guidelines, the issue of AMD is repeated several times. To avoid duplication, categories could be chosen according to the issue. This requires that the issues are known. The categories may therefore be defined after the scoping process and public consultation. For the use in GIS the number of categories should be kept to a minimum to make it easier to create relationships between categories. For example AMD can be combined with other types of potential pollution such as sewage and stormwater (to form one category). Cumulative impacts can be predicted for each category as well as between categories (by establishing links).

The following four categories are suggested[18] for the analysis of key issues at Savage River: "Landform and Landscape", "Pollution", "Ecosystems" and "Socio-economic and cultural". An important aspect of the environment is the landform. Landform has an effect on soil stability, drainage and erosion. Slope and aspect are key controlling factors for re-vegetation and habitat re-establishment (Environmental Protection Agency 1995). Landform needs also to be considered for other land uses. Waste dump pit design during mining can already contribute positively to future rehabilitation needs or success (Environment Australia 1997; Environment Australia 1998). An overall perspective of the mine in the context of the surrounding local and regional landscape is needed to guide landform design aspects of the rehabilitation program. This will ensure better integration of the mine into the landscape and the particular character of the region (Forestry Commision of Tasmania 1990).

Pollution is a primary concern of mining activities and this may take several forms (Environment Australia 1999 a). The prevention of pollution is one of the most important principles in EIA. Pollution can occur in water, soils and air and depending on the scale, effect human health and ecosystems. At Savage River, the most serious risk is water pollution from acid producing waste dumps (ABM 1996). Selective storage of waste material and design aspects of the mine have however reduced this risk (ABM 1996). For the EIA of key environmental impacts, AMD potential of future waste material and effects on the water catchment and soils need to be predicted. Apart from waste dumps, other mine structures such as pits and

[18] These categories are based on the key issues identified in this hypothetical EIA and are used for demonstrating a GIS- based EIA. In reality, there may be also others.

tailings and areas where ore is stored and processed also have potential to produce AMD and need to be included in the EIA. Risk assessment may be undertaken to predict the behaviour of designed structures under extreme conditions (rain fall, earthquake). Iron ore mining also has the potential to cause air pollution at all stages of mining (Ripley, Redmann et al. 1996). Air pollution occurs mainly from the extraction process and can be considered a minor threat due the use of dust suppression methods and wet climate (ABM 1996). Modern processing plants use filters to prevent air pollution from pelletising and fuel burnt for the processing of ore (Ripley, Redmann et al. 1996). Another source of pollution is transport, storage and handling of hazardous material such as oil and chemicals. This may is best included into risk assessment.

Another category in EIA deals with impacts on ecosystems. Vegetation contributes to landform stabilisation by reducing run-off intensity and improving infiltration (EPA 1995 h). At the same time vegetation is dependent on landform aspects such as slope and aspect and susceptible to pollution. Healthy vegetation is the basis for stable and varied ecosystems. Assessment of key environmental impacts need to focus on the type and area of ecosystems affected and possible mitigation measures such as progressive rehabilitation (EPA 1995 h).

A fourth category is concerned with socio-economic and cultural impacts. While socio-economic aspects can be collected from available local and regional statistics, information on cultural aspects such as recreation use (bushwalking, fishing and photography) and heritage values are most likely to be collected during the public consultation period. Key aspects may include the number and variety of recreation features and the amount of use. Access to the mine during mine operation and future land use are also likely to be assessed in detail. Possible measures to maintain or increase public use may be by making the mine area accessible during the mining period (for interpretation either regularly or at open days) and after mine closure infrastructure (such as roads and buildings) to be converted for postmining recreation use (ABM 2001). Cultural heritage values may also be of importance and may be assessed in context with other mines in the regions.

As the EIA is part of an environmental management system, the categorisation should also take into account aspects of environmental management such as monitoring and rehabilitation. This makes the transformation the later into EMS easier. The order chosen for in depth analysis in EIA is therefore based on priorities in rehabilitation. Because impacts are likely to be interrelated, the EIA analysis should be undertaken as an iterative process. Figure 5-5 shows the categories (components) suggested for key environmental impact assessment at Savage River.

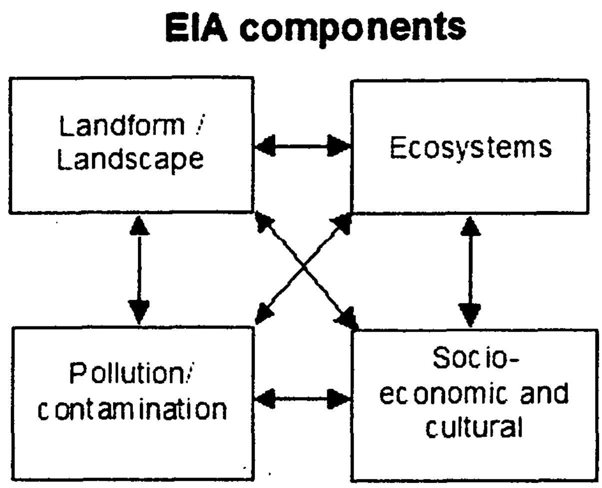


Figure 5-5: Categories for GIS analysis

5.7 Summary

In this Chapter, the use of GIS for screening and scoping has been discussed. It is suggested, that GIS is used to collect data on the location of the mine, the history and the current environmental and socio-economic situation. This stage includes the collection and use of all relevant data and information. The main task at this stage is to prepare all data for use in GIS. This requires manipulations and conversions (see Chapter 2). After all data is integrated in GIS, the most important GIS tool at this stage is the overlay tool. This allows the combination of various information to be visualised and analysed together and can answer questions such as "Where is the mine in relation to streams?" or "Where are historic mine structures". Missing baseline data and the need for more detailed data would also be identified during this stage, including information of historic pollution. Considerable thought needs to be put into the presentation of scoping outcomes as this is the stage were all interested parties including the public are involved for consultation and decisions are made for the need of further detailed analysis. In the next stage of the EIA, the key issues as represented in these four categories need to be analysed in detail. GIS requirements for this are discussed in the next chapter.

CHAPTER 6 GIS FOR KEY IMPACTS ASSESSMENT

6.1 Introduction

In the second stage of the hypothetical EIA, an in-depth analysis is undertaken for grouped key environmental issues from the scoping stage: landform and landscape, water and soils, flora and fauna and socio-economic aspects.

In the first step, more detailed spatial and non-spatial environmental and socio-economic data would be collected. Some of the information needed for the EIA could be collected from the Waratah-Wynard Municipality (e.g. planning zones, environmental issues, socio-economic aspects of the area etc.), DPIWE (The LIST, specific environmental data from surveys) and MRT. Additional sources of information are *Environment Australia* and associated databases and the *Australian Spatial Data Directory* (ASDD).

Mobile GIS could be used for field inspections and additional surveys. This would allow all spatial and non-spatial information to be available at hand in the field, if needed as well as immediate integration of new data. Also, the exact location of stations for monitoring could be determined. A digital camera can be useful to take pictures of sites, where data is taken. For analysis, GIS and non-GIS methods would be considered and compatibility with other programs checked.

6.2 Data requirements

The assessment of key environmental aspects in the next EIA stage requires detailed up-to-date and accurate information to be displayed at large scale. Field inspections may be required to supplement existing mapped information. Orthophotos produced with GIS can be useful at this stage. In order to map existing mine structures, height accuracy is needed. A common method in GIS is to use a *digital elevation model* (DEM), which is usually derived from aerial photos. Resolution of the DEM depends on the flying height, which determines the scale of the photographs (Wolf 2000). The derived DEM consists of grid cells, each of them containing easting, northing and height (normally stored for the middle of the cell). It follows from this that the lower the resolution of the DEM, the lower the accuracy for three-dimensional measurements (slope, aspect, volume) (Burrough and McDonnell 1998). DEMs are predominantly used in modelling (i.e. hydrology, soil and pollution) (Band 1999; Burrough 2002). An alternative to the raster elevation model is a *Triangular Irregular*

Network (TIN). This method creates irregular triangles from nearest points (usually through *Delauny Triangulation*). TIN has the advantage that *breaklines* can be defined, where the terrain abruptly changes (Burrough and McDonnell 1998). This is especially of use for artificially created landforms as the case in mining. Both terrain models are supported in ArcGIS 8.3 and Manifold 5.50.

Airborne and terrestrial laser scanners are another source for high accuracy terrain data and are becoming more widespread for various applications with advancement in surveying technology (Wolf 2000). Laser scanner collect a large number of points, which can be directly used as highly accurate three dimensional sample points (Wolf 2000). Usually laser scanners come with special image processing software (e.g. Riegl Riprofile or I-Site Studio) and compatibility needs to be checked. Accurate terrain data (1:500 or 1:100) is especially needed for design of mine structures. However, high accuracy also improves terrain related modelling outcomes such as drainage, erosion and pollution dispersal (Gessler, Moore et al. 1996). An evolving source for accurate terrain data is satellite imagery (SAR), which can detect surface changes to an accuracy of millimetres (Dowman 1999). An overview for different remote sensing data and resolution can be found in Van der Meer et al. (2002). Remote data collection is beneficial for areas that are difficult to access due to steepness or hazardous materials (pits and waste dumps). An example for a laser image of a mine site in given in Figure 6-1.

For detailed analysis the aspect of time, in the form of time-series data, may be employed (Patil, Annachhatre et al. 2002). This has a vital role for providing an understanding of processes and for making predictions. For numerical modelling and spatial interpolation, sample data needs to be collected and parameters determined. This can involve data from long-term observations and/ or laboratory tests (Wels, Lefebvre et al. 2003). In an ideal situation, contamination resulting from previous mining activity would have already been successfully treated and sufficient monitoring data collected prior to re-development. In such a case, an environmental database would exist and contamination types and rates for all existing mine sites would be known. If this information and data was stored and provided by the planning authority or Board, efficient and more consistent mitigation measures could be developed for mining re-developments. During the mining period, the database would be extended with monitoring data including where operations and incidents have occurred and subsequent treatment made to manage pollution.

Beside accuracy, consistency of datasets (scale, currency, projection) is essential for spatial analysis to minimise errors and uncertainty. A common understanding in GIS is that larger amounts of data increase the possibility of errors and error propagation (Burrough and McDonnell 1998). This is because every survey has a certain error potential. It is also true for individual data layers as these are often compiled from different data sources (see metadata information provided by ASDD). Digitising from aerial photos and paper maps as well as conversion of raw data provide sources of error and accuracy. When using several layers, the grid size needs to be the same for all layers if possible. This can be a problem as data is captured at different resolution. For example the DEM for Tasmania at 1:250,000 provided by DPIWE has a grid size of 1km, whereas the grid size used by the Australian Greenhouse Office for mapping of threatened species is 3km (metadata in ASDD). This difference can be overcome by recalculating the grid size, where the higher resolution is reduced to the lower one, which will result is loss of accuracy. It is therefore vital to keep the original data for later reference and other uses. Results of detailed assessment of key environmental aspects would be included in the DPEMP. Data documentation, storage and presentation are discussed in the next sections.

6.3 Landform and landscape

6.3.1 Impacts on landform and landscape

In Chapter 3, the close relationship between landform and landscape was discussed. Landform is an essential factor in mine planning and is closely associated with extraction methods and handling of ore and waste material. It is important to re-create basic landform functions such as stability and drainage after mining has stopped. Final slope steepness and aspect (relative to the sun) can influence success of re-vegetation and land use after mine closure. Savage River is located in a high rainfall area with 1930 mm mean annual rainfall and 232 days of rain (BOM 2004). Stability and erosion of mine structures such as tailings dam embankments, pit walls and waste rock dumps need to be considered with respect to climatic aspects (ABM 1996). Unstable waste dumps and pits are a risk to mining operation and also to the environment as these can increase the potential for AMD and inhibit or slow down the rehabilitation process (Environment Australia 1997).

At a broader level, the mine needs to be re-integrated in the surrounding landscape. This ideally should occur progressively throughout the life of the mine. The final shape may not be anything like before mining started, especially with open-cut mines. Although the location of mining is dictated by the ore and the landform is determined by mining operation, some flexibility in shaping the landform may exist and should be explored at an early stage to ensure that the post-mining landform integrates with the surrounding landscape. Open cut mines have potential to strongly impact on visible landscape values (Turner 2003). However good planning can reduce the degree of this impact. Landscape character assessment can provide guidance with the way the mine appears in landscape and how it might be designed (and later rehabilitated) within the context of the surrounding landscape, and reduce negative effect for the general public and visitors (The Countryside Agency and the Scottish Natural Heritage 2004). At Savage River, it is essential to consider that the mine is situated in a mountainous terrain. Previous mining here with the creation of deep open cuts and massive waste rock dumps has dramatically changed the landform at the mine. These changes were already highly visible on the 1:25,000 topographic map "Savage River" from 1987 and impacted on the surrounding landscape.

6.3.2 GIS analysis

Landform

Using 3D models, existing landforms can be shown and planned changes simulated. This needs high quality elevation data. Highest quality is achieved by using laser scan imagery (see example in Figure 6-1).

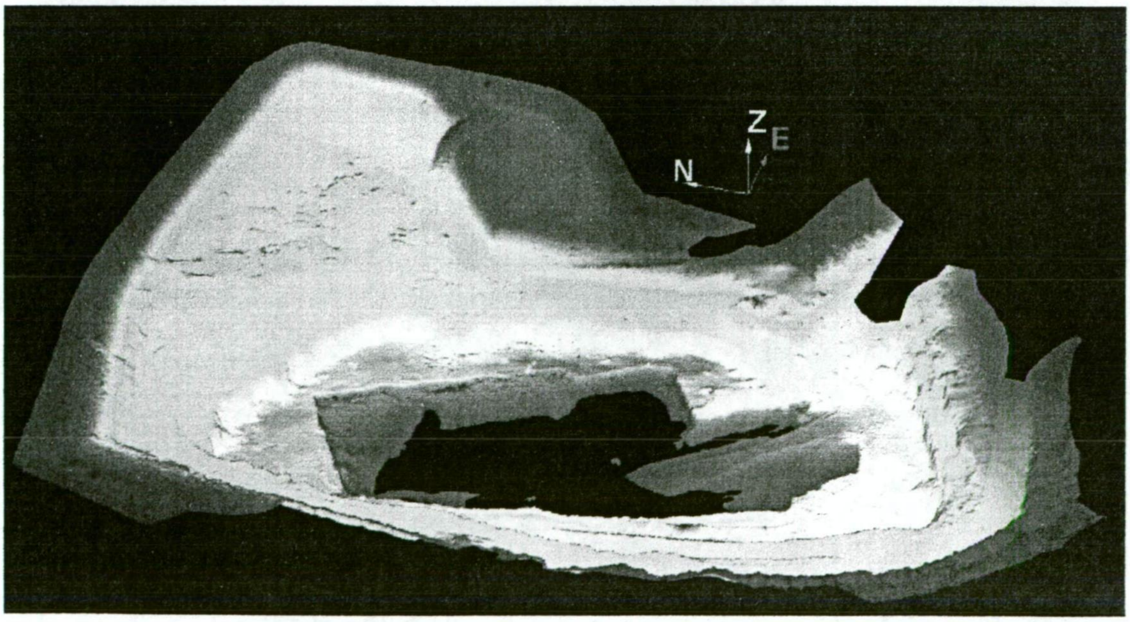


Figure 6-1: Laser scan image of the Cement mine in Railton (Tas.)[19]

[19] using a Riegl LMS-Z210, source: Lester Franks Survey and Geographic, 2004

Alternatively, an available elevation model (DEM or TIN) can be used. The DEM for Tasmania is based on aerial photographs and has a pixel size of 25m. This data is not accurate enough for detailed slope analysis. For higher quality data a DEM needs to be done from high-resolution aerial photos, 3D laser scanning or surveying. The collected height information is the basis to calculate slope, aspect, profiles and 3D views. Contours, shading and 3D views of mine structures (i.e. pits, dumps, dams etc.) can be generated. Time series can be undertaken for visualisation of the different stages of mining as well as the final landscape after rehabilitation. Cross sections are another useful tool for analysis of detailed changes to landform.

In combination with engineering programs and AutoCAD, hazards assessment could be undertaken (possible pressure on embankments, slope stability etc.) and results imported into GIS for spatial display of risk areas. Using high quality elevation data, processes such as erosion and drainage can be simulated considering different environmental conditions (e.g. rainfall, wind direction). ArcInfo functions included in ArcGIS provide algorithms for hydrological modelling, when a DEM and hydrology data is available. One example, where an erosion model was used in mining was the Jabiluka mine in the Northern Territories. The "SIBERIA landscape evolution model" was used to predict sediment transport from the mine into streams (Boggs, Devonport et al. 2001). Data input consisted of rainfall data, a DEM and remotely sensed imagery. The model is based on elevation variation and channel network development for each cell of the DEM. The model supports Monte Carlo simulation to show probability distributions and reduce modelling error. The developers also planned to integrate interactive functions. For Savage River this model could be used to predict transport of sediments from waste dumps, pits and tailing embankments into Savage River. However the model for the Jabiluka mine used a simplified form of the Revised Universal Soil Loss Equation (RUSLE), ignoring rainfall erosivity (Boggs, Devonport et al. 2001). This means the model was applicable in areas with low variation of annual rainfall. The rainfall at Savage River varies between 82 mm in February and 236 mm in July (ABM, 1996). Thus adjustments for local conditions would be necessary. Also, rainfall erosivity is considered the most accurately computed element of RUSLE (Toy, Foster et al. 1999). At Savage River, the model would need to be applied using a more comprehensive range of inputs. Figure 6-2 shows the general GIS process for landscape analysis in EIA.

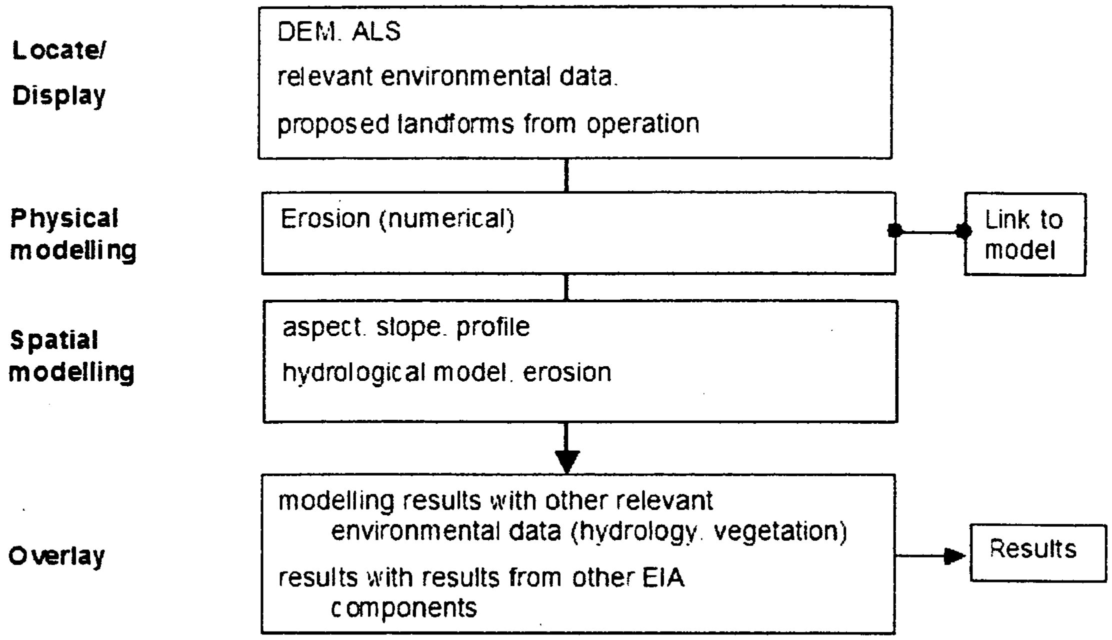


Figure 6-2: GIS process for landform of Savage River

<u>Visual impacts</u>

The primary function of GIS in landscape planning has been to perform overlays of different aspects (Turner 2003). The Derbyshire Coalfield is one example, where a GIS-based landscape character assessment approach has been applied in the context of mining to reduce visual impact on the landscape (Countryside Agency of England and the Scottish Natural Heritage 2004) (see Figure below).

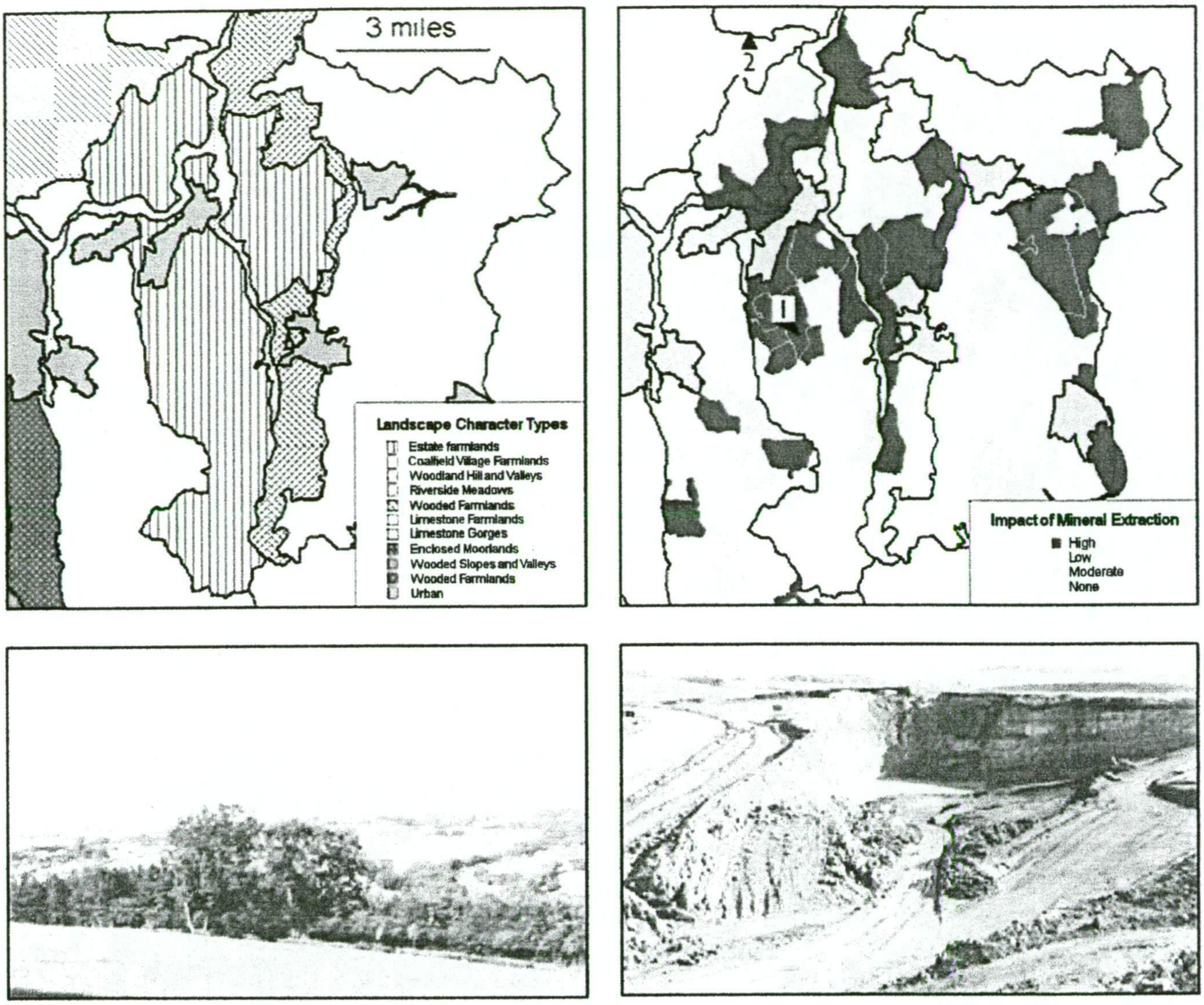


Figure 6-3: Visibility study to determine the impact of mining on the landscape[20]

In Tasmania, landscape characterisation was developed by the Forestry Commission (1990) to guide assessment of scenic values. Although very broad, it gives on overview for the assessment of landscape values at the regional scale. Examples where the visual landscape values have been included in planning in Tasmania are the Meader Valley study (Inspiring Place Pty Ltd 2002) and the Musseleroe windfarm study (Inspiring Place Pty Ltd 2002). A pilot study for landscape character assessment has been undertaken for the Tasman Peninsula in 2004. The Figure below shows the seen areas (in blue) from Palmers Lookout (purple triangle).

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[20] The Countryside Agency and the Scottish Natural Heritage (2004). Landscape Character Assessment. Guidance for England and Scotland. Use of geographical information systems and other computer methods. Topic Paper 4. **2004**.

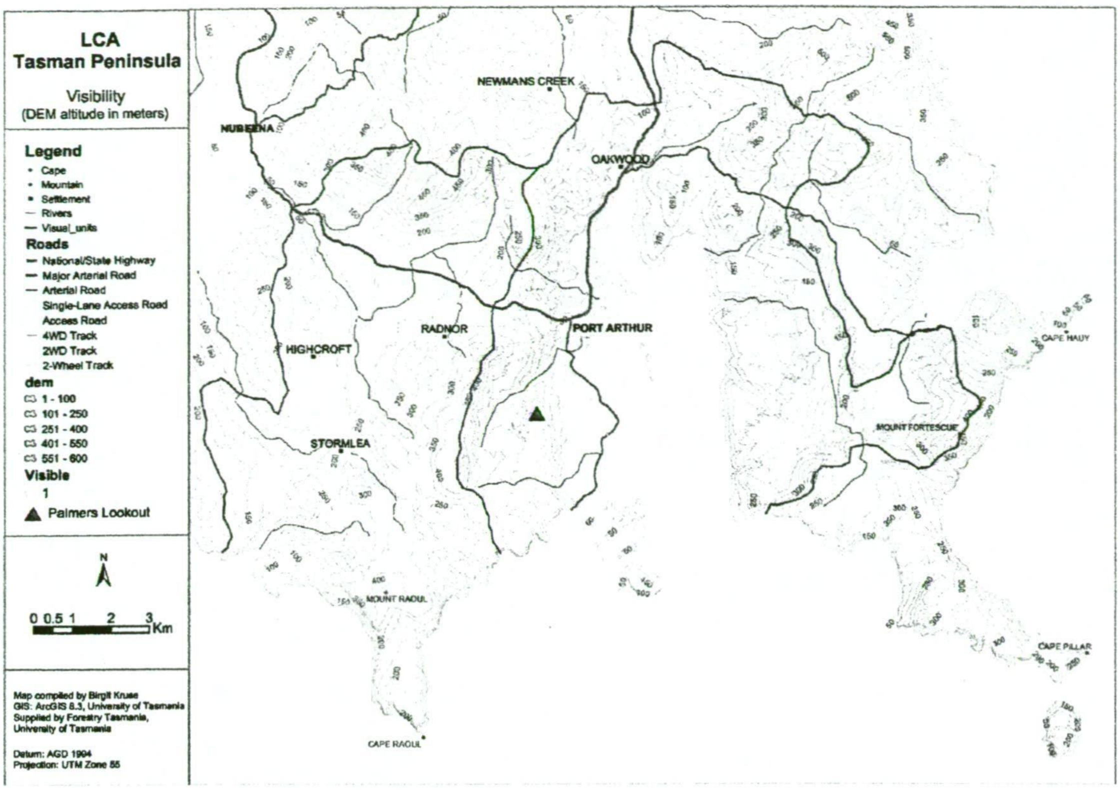

Figure 6-4:Example for a seen area analysis (areas in blue are seen areas)

At Savage River the process of landscape impact assessment consists of three steps: Locating and adding data to the GIS, generating a 3D model and performing seen area (viewshed) analysis. As no statewide landscape character assessment has been undertaken today, available information on the landscape of Savage River (e.g. from the Heritage database and Tourism Tasmania) and knowledge from local and regional residents is collected in order to identify cultural values of the landscape (recreation, mining heritage, Aboriginal sites). Some information needs to be converted to spatial data, for example descriptions of areas or photographs. In the next step, the visual impacts are predicted for different stages of the mining operation using seen area analysis. From known viewpoints, visibility of the mine is simulated. Results are utilised to identify locations for possible screening vegetation. Viewshed analysis could later also be used to find suitable locations for viewing platforms to be used later by the public. The results of the landscape impact assessment are stored in the central database for overlay with other EIA components.

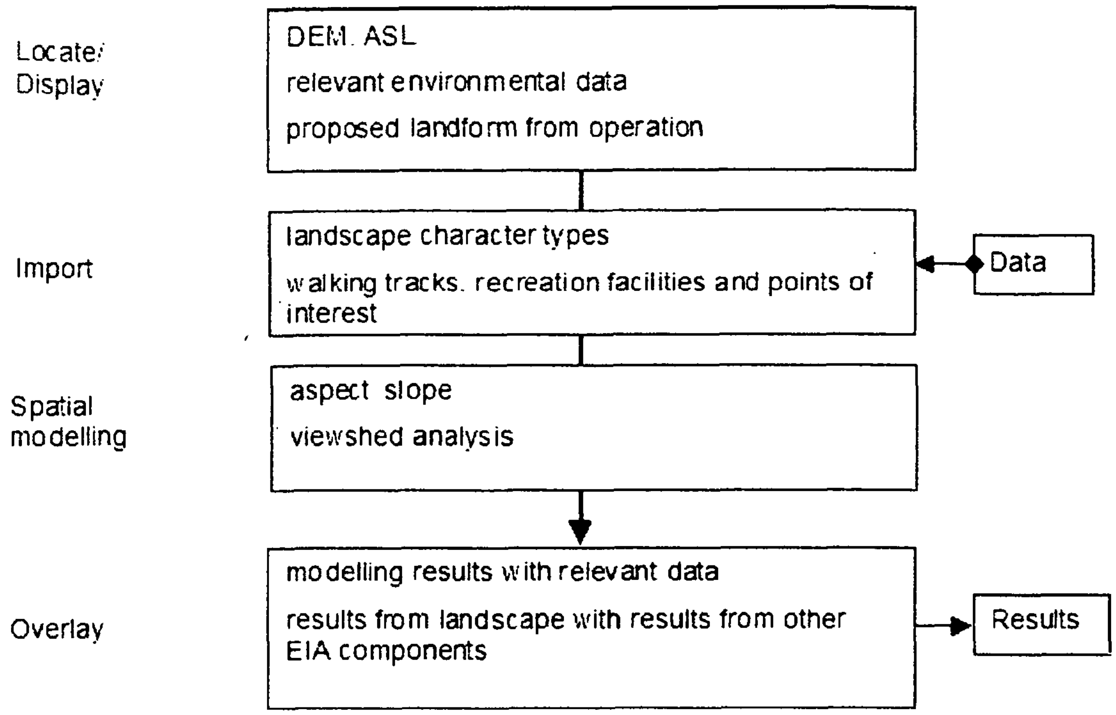

Figure 6-5: GIS process for landscape at Savage River

6.3.3 Discussion

Although, the scenic values of the landscape are considered important in Tasmania (RPDC 2003), visual landscape plans are not required as part of development proposals under the RMPS. However, visual amenity was included in the environmental management plan for Savage River (ABM 1996). Due to the massive scale of changes, which have taken place already, changes due to the present re-development would not be expected to have as great an effect as in the previous mining stage. Nevertheless, the area will be extended and the size and shape of structures enlarged. Also river diversion and tunnelling would create a considerable change to the existing natural drainage pattern and affect also the visual appearance.

As Savage River is located close to national parks and conservation areas, which provide high wilderness experience in Tasmania, it is favourable to screen mining activities using vegetation banks (Down and Stocks 1977). To ameliorate the overall visual impact of large-scale mining and the effect for distant viewing, the gross size/ scale and the visual contrast due to colour and brightness needs to be considered in visual planning. Visual impact would also be significantly reduced by progressive rehabilitation as already considered in the DPEMP (Environment Protection Agency (EPA) 1995 h; Australian Bulk Minerals (ABM) 1996). Although Savage River is not as significant in mining and cultural heritage and is not situated as strategically as

Queenstown for tourism, it may still be beneficial to keep some mining structures. Visual landscape analysis may need the most input from local communities and unconventional and non-GIS methods may be needed (sketches, photocollages) to enhance public participation aimed at reaching a broadly accepted agreement on management (Al-Komady 1999). The analysis of these aspects affects the design of landform structures (waste dump shapes, tailing dams etc.). During the operation period, viewing platforms near the mine could attract visitors to experience the large changes in the landform due to mining and the rehabilitation processes taking place.

6.3.4 Summary

By considering landform and visual landscape aspects together, it is possible to plan for stable landforms, to be safe during mining and suitable for rehabilitation (i.e. drainage and erosion minimised) as well as re-integrating the landform in the broader landscape. 3D analysis of the landform needs high quality elevation data. While slope, aspects and profile functions are used for prediction of landform behaviour, viewshed analysis and 3D views of the mine landform structure display impacts on the visual landscape.

6.4 Pollution and contamination

6.4.1 Impacts on water and soils

Pollution here refers to present and future release of harmful and poisonous substances while contamination is defined as deposits accumulated from past mining activities. Pollution from mining can occur in surface water, groundwater, soils and in the air. Each type of pollution depends on several factors and may be interrelated. At Savage River, air pollution has been determined as a minor issue due to low levels of discharge from the mine, available dust suppression methods and the wet local climate.

Assessment of water is essential as water pollution can threaten flora and fauna, affect drinking water quality on communities downstream and recreational use of Savage River. Polluted water can move downstream and cause problems far away from the source. Mining at Savage River is believed to have an impact for 30km downstream (DPIWE 2001). A similar situation can be found at the King River and upper Macquarie Harbour as a result of mining at Mount Lyell (see Chapter 2). The most serious water contamination in mining is caused by AMD from waste material, tailings and pits (for details on AMD see Chapter 2). The two specific aspects that make AMD difficult to control at Savage River are the steep and incised topography and high annual rainfall. Apart from mining operation, pollution can be caused by spills and poor handling of hazardous material (Environment Australia 1999 a). Contaminated soil from AMD and other forms of pollution hinders the natural re-establishment of ecosystems and conflicts with rehabilitation programs. The assessment of disposal or treatment methods are therefore of major importance in EIA.

Impacts on soils also need to be predicted. Goovaerts et al. (1997) developed a method which combines measurements of metal concentrations with a geological map. This method may be used to predict soil pollution near mine structures. As pollution differs depending on the soil type, different impact-level areas may be determined based on a high quality soil map or measurements. This could be used for risk assessment (oil spill etc.). The following section focuses on the use of GIS for prediction of AMD.

6.4.2 GIS analysis

GIS can be used for inductive and deductive modelling (Skidmore 2002). Both can be used to give an understanding of pollution effects. For inductive modelling the input parameters are known and the impact is predicted. For deductive modelling the outcome in known (from sample sites) and the sources of impact are reconstructed. In both cases a process model is developed and parameters need to be defined. In the absence of environmental data and parameters, a combination of inductive and deductive modelling is often used (Reed, Brown et al. 2002). Several studies have been undertaken for prediction of AMD in the mining areas of the West Coast using GIS. An overall GIS-based study was undertaken by Gurung (2001). In this study acid-forming potential was mapped from samples and interpolated, using "Inverse Distance Weighting" (IDW). IDW is best used for smooth surfaces using regular distributed measurements, as the method is sensitive to clusters and outliers (ArcGIS Desktop Help). A more accurate interpolation can be achieved by using the "Kriging" method, where weights for interpolation are defined in a semivariogram and thus the distribution of measurements can be taken into account. Kriging has only recently become available in GIS. Other models used for AMD modelling include run-off and erosions models, geochemical reaction models, airflow models and groundwater flow model (O'Kane and Wels 2003). In general, AMD models require large amounts of data (Gumbricht 2000; Gogu, Carabin et al. 2001; Wels, Lefebvre et al. 2003) and data needs to be available for at least a year to take into account seasonal changes (Morris and Biggs 1996; Wels, Lefebvre et al. 2003). In Tasmania, baseline data for acid drainage is limited (RPDC, 2003) and was not sufficiently available for Savage River at the time of the DPEMP (Goldamere Agreement 1996). A combined inductive and deductive approach is therefore necessary.

Two methods can be used to calculate pollution from previous mining activities. One involves the use of historic aerial photographs and documents on mining history (Kent, S. 2004, pers. comm.). From aerial photographs (stereopairs) a DEM can be created and the volume of waste dumps measured. Using hydrological modelling, drainage patterns can be determined to give an understanding of dispersal of pollutants. Another method calculates the historic amount of waste material by using AMD data collected at sample sites and combining these with environmental conditions. Impact of future mining is predicted using the historic rate of pollution and applying this to the mining project and conditions. This method requires that the acid forming conditions are similar in the historic and new waste rock dump.

Without suitable historic data being available for the site, predictive modelling relies on sample measurements taken from the field. In this case, rock samples are collected within the area of the planned mine structures and acid forming potential is tested. The data is interpolated for the whole area. To ensure that the sample sites represent the ore and rock types of the whole area it is important that samples are collected in sufficient numbers and density and changes in rock type are taken into account. For accurate spatial contamination, simulation knowledge of diffusion processes and parameters is required. This need the use of available GIS extensions, customisation or links to independent (i.e. non-GIS) modelling programs. For example geochemical modelling programs allow modelling of mass balances, phase diagrams, flows and reactions paths not available in current GIS packages (Lottermoser 2003). Import of the results from these models depends on compatibility with the GIS package. For customisation, existing mathematical models could be used taking rainfall, infiltration, time and other factors into account. This requires experience with GIS programming languages. A similar modelling process can be undertaken for simulation of seepage potential from pits, tailing dams and stockpiles.

The results of pollution prediction models resulting from waste dumps and other mine infrastructures is then applied to hydrological modelling of streams. Today, no single model is available to predict changes of hydrological flows. A combination of models have been used to simulate changes of water cycles on a regional scale (Olsson and

Pilesjo 2002). In GIS digital elevation models are used to predict flow regimes based on slope. Similar to pollution modelling of mine structures, hydrological modelling of streams relies on a wider range of parameters. At the Rosebery mine, the interaction of surface waters, groundwaters and acidic mine waters was analysed to predict water quality (Evans, Cooke et al. in press). A similar hydrochemical model is needed for Savage River to understand the effects of waste water on ground and surface water. Coupled with a DEM-based hydrological model in GIS, flow behaviour and water quality change could be simulated. Beside pollution from mine infrastructure, siltation by mine waste material in combination with high rainfall is another aspect that needs to be considered.

Figure 6-6 shows the simplified process for contamination modelling using a combined inductive/ deductive approach. In this process, GIS is used for displaying environmental conditions, locations of sample sites, spatial modelling, import of other models. The results can later be overlaid with the results of other EIA components.

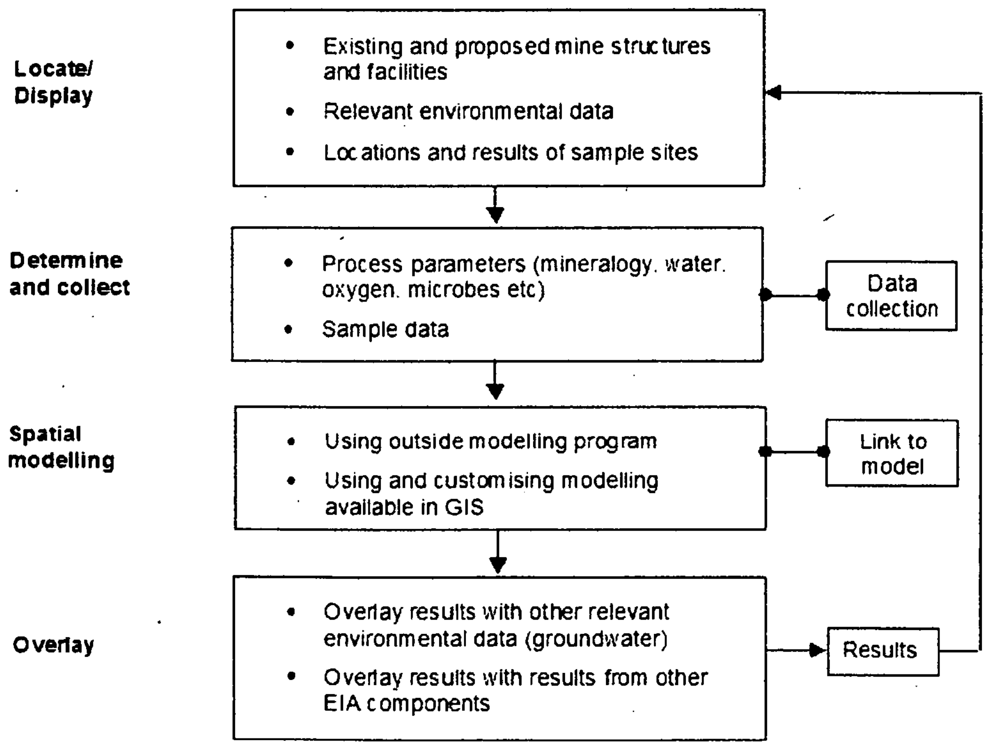

Figure 6-6: GIS process for contamination modelling and spatial simulation at Savage River

In a next step after key environmental impact assessment of pollution and contamination due to waste material, mitigation measures need to be developed. This could include limiting the amount of waste material; improving handling methods; covering and stabilising of waste dumps and waste water discharge management (Environment Australia 1997; Environment Australia 1999 a; Environment Australia 1999 b). Locations for selective handling of waste material can be mapped in GIS. Also sample sites can be stored for updates of monitoring data (see Figure 6-7). In co-operation with the SRRP project, data from monitoring stations downstream of the mine could be included. An interactive map displaying different measurement values (e.g. pH, metal content, turbidity) could be used for monitoring. By overlaying with recent aerial photographs, satellite images and vegetation maps it is possible to show the impact of water pollution on riparian vegetation. The use of GIS for key environmental impact assessment in ecosystems is demonstrated in the next section (6.5).

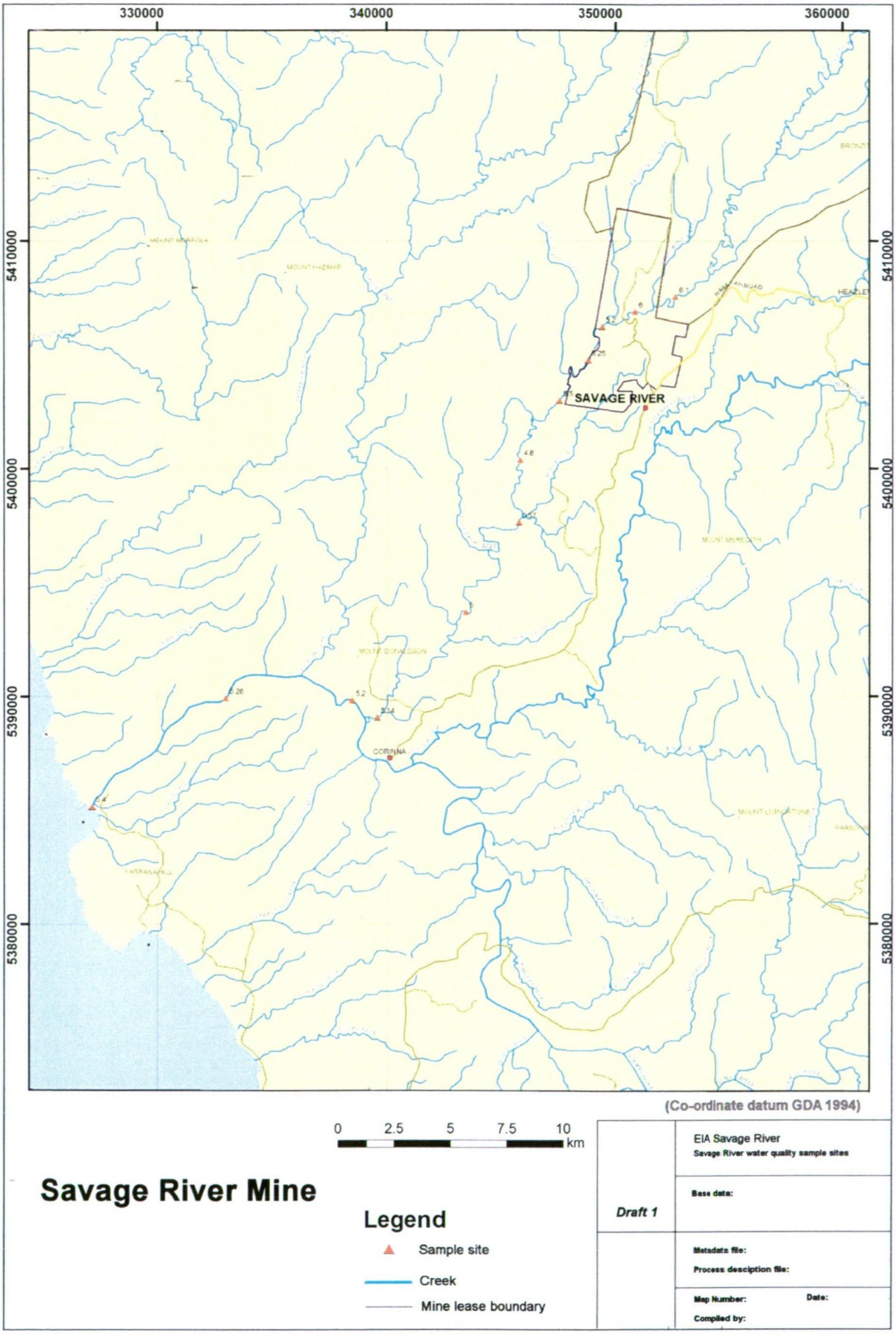

Figure 6-7: Draft map for water monitoring stations at Savage River

6.4.3 Discussion

Waste rock dumps are considered to have caused major impacts on water quality in the past (ABM 1996). They therefore need special attention in EIA. Waste dump design influences AMD, including separate storage of waste materials and use of an impermeable cover on the waste dump to avoid AMD in the future (ABM 1996). Tests from above and below the modified Broderick Creek waste dump revealed acceptable water quality levels. Beside waste rock dumps, the design of pits, tailing dams and stockpiles need to be considered for AMD generating potential. As well, handling and storage of other toxic material such as oil and chemicals can be a source for pollution. This may be assessed under risk assessment together with natural hazards.

Pollution and contamination models require extensive knowledge of hydrological, geophysical and geochemical processes involved. In order to make such a model available for non-GIS experts in EIA, a sophisticated simulation tool could be developed. Such a tool should provide an easy to understand step-by-step process, for data input (e.g. number of points per area, distribution) and prompt warning messages for missing or wrong information. It also needs an interpretation of the result. The ultimate goal of this tool is to create a 3D simulation to predict the evolution and spread of toxic waste material from mine structures to external areas.

A model is an abstraction of reality. Inaccuracy due to the absence of knowledge of the process and parameters data can be best overcome by using an iterative process and using a time series (Olsson and Pilesjo 2002). Data collection in the field should also be repeated for three reasons:

- Sample points and/ or survey methods need to be changed
- Other data may need to be collected before the process is repeated
- A longer observation period of may be necessary

6.4.4 Summary

Pollution and contamination are major concerns in mining especially in the form of AMD and needs to be addressed in EIA. Pollution modelling requires a good knowledge of process involved. As the AMD process has a vertical component, prediction of acid mine drainage of waste dumps, pits and tailing dams in GIS needs to be three dimensional. It must take into account aspects such as rock type, oxygen availability and temperature variations. Ideally, GIS analysis should show changes over time. For wider use in EIA by non-modelling experts, greater decision support would be needed for parameter input. This should take the form of a step-by-step procedure with guidance for data entry.

6.5 Ecosystems

6.5.1 Impacts on ecosystems

Ecological assessment in EIA can usually make use of existing information (Morris 1996). Additional fieldwork is necessary for more specific information and updating of available information. In areas that have been disturbed for a long period, this may however not be the case. As the mining redevelopment at Savage River covers previous as well as new (extended) areas, it may not be possible to separate ecological effects in both areas. Because DPIWE is responsible for management and rehabilitation of previous areas and ABM for the effects of current and future mining, impact assessment needs to be undertaken in co-operation. Results of trial re-vegetation are necessary to accurately predict the impacts of mining extension.

Rehabilitation of historic abandoned mine sites is usually a complicated process, as information of pre-mining vegetation does often not exist. Estimations need to be made from surrounding and remnant vegetation, historical aerial photos and other available information (Leeson 2004).

6.5.2 GIS analysis

GIS is an effective tool for ecological assessments. An overview of GIS analysis methods can be found in Aspinall (1999). Using GIS, all available information on the environmental together that of proposed mining would be located and stored in a GIS database. GIS could then be used in the following analysis processes:

- Identify existing flora and fauna and conditions
- Identify location of threatened species
- Determine areas of protection and corridors including riparian vegetation and neighbouring areas
- Identify locations for potential of weeds, diseases and fire risks
- Determine conflicts between proposed mining and ecosystem protection

- Determine and display mitigation options

Modelling software has been developed, which may be linked to GIS. These include BIOCLIM and HABITAT (Aspinall 1999). An integrated environmental model, operating in ArcView (ArcAvenue), has been developed by Aspinall and Pearson (2000). As discussed earlier, models need to be based on existing examples and adjusted to the local situation. As Tasmania's ecosystems are unique from those of mainland Australia or other parts of the world, existing outside models for example models created for rehabilitation of ecosystems in Western Australia may not be of use at Savage River without refinement.

In the absence of models, the EIA at Savage River may be strongly dependent on existing data and knowledge and field surveys. The quality of the EIA depends therefore on the type, amount and accuracy of available information, as well as the analysis methods, including classification, data integration, principles guiding overlaying, queries etc.

An initial step in analysing potential impact on ecosystems would be to determine from existing information the flora and fauna on the mine site and their condition. This could be done by displaying large-scale vegetation maps, aerial photos and satellite images. Next, it would be necessary to identify if threatened flora and fauna species occur on the mine site. This is required by the EPBC Act and EMPCA. Several methods are possible. One method is to query the threatened species database (DPIWE), which however can only give a general indication, as it consists of recorded sites rather than systematic state-wide surveys. Another method would be to query a detailed vegetation or fauna layer in GIS. This can only be done, if the data is detailed enough to identify individual threatened species. A third method is to combine several associated environmental conditions (e.g. geology, terrain). For example a threatened plant species may require a certain soil type or occur only within a specific altitude range. Figure 6-8 shows an example of overlaying vegetation and geology in order to identify possible areas of threatened flora species. Fieldwork would then be needed to verify or dismiss the actual occurrence of threatened species in the identified areas as well as to record the accurate location. The same could be done for threatened animal species by overlaying habitat conditions.

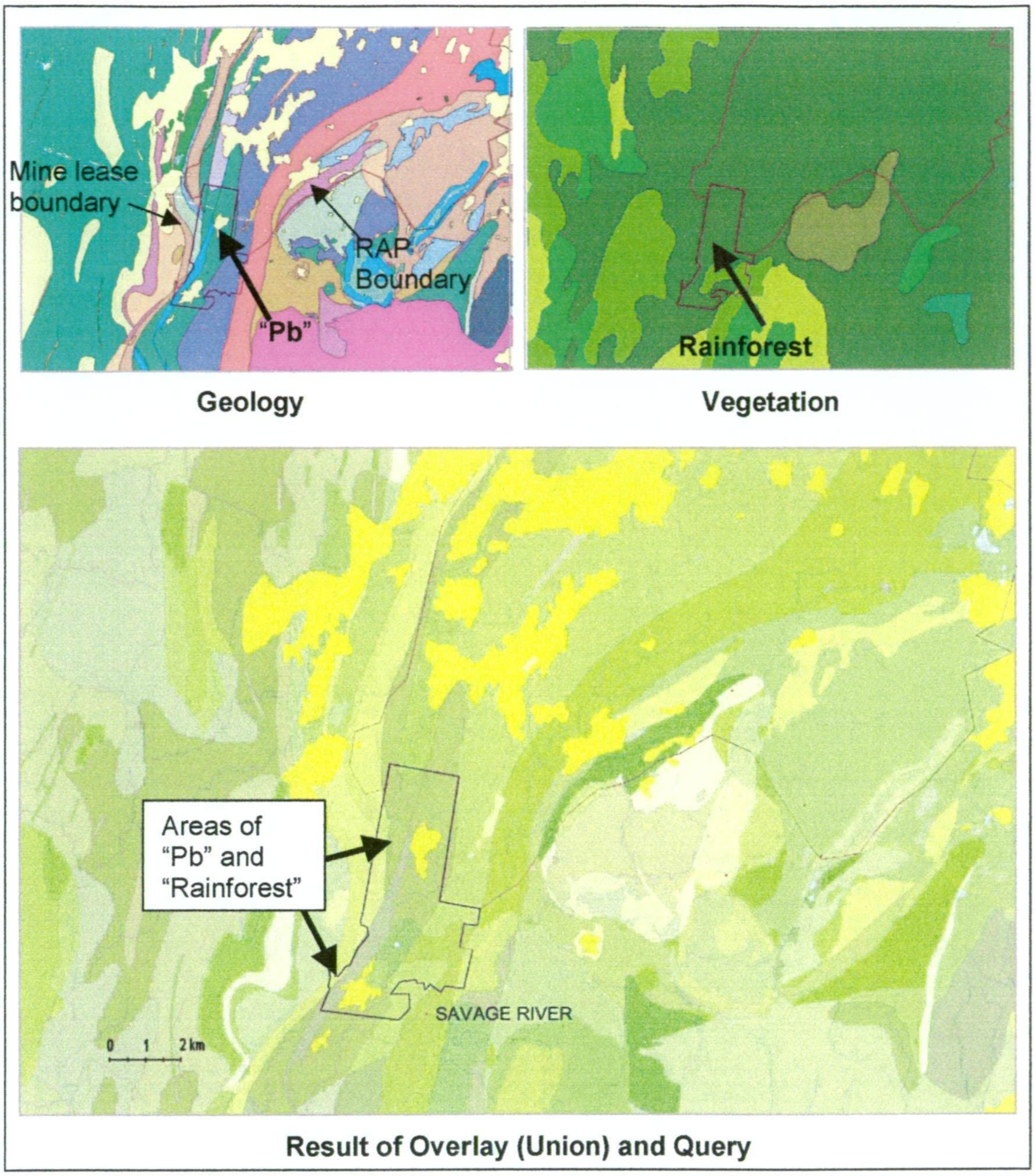

Figure 6-8: Union of two GIS layers and a query

In a next step, a buffer could be created to protect these species. From an ecological point of view, plants belong to plant communities and provide habitat for fauna. It is therefore favourable to protect larger areas and provide corridors for animals within the mine lease and to neighbouring areas. Furthermore vegetation can be grouped in different priorities. Riparian vegetation is important to minimise erosion. Principles have been established within the Forest Practices Code. The recommended buffer width depends on the stream class and is usually extended to include steep riverside slopes (Forest Practices Board 2000). A classification of stream is available for the whole state. Guidelines for riparian vegetation have also been developed by DPIWE

(2003). Ideally, the protected riparian vegetation would be connected with the already protected areas created for flora and fauna in the surrounding (e.g. RAP areas).

After all critical areas have been identified, the result is overlaid with areas proposed for mining as developed from ore occurrence and common mining methods. This may reveal conflicts where full protection or mitigation strategies are required. A draft EIA map for ecosystems may be similar to the map in Figure 6-9.

The map shows existing and planned mine structures (pits and waste dumps) for the northern part of the mine area as well as identified threatened species and a significant geology type. Threatened species, which would be lost in the case of mine area extension, are highlighted using a different symbol. Potential for flora and fauna protection including riparian vegetation area also displayed. The 1:25,000 map of Savage River was chosen as a background layer. The example shown here is made from available large-scale data, which is too broad for detailed analysis. Locations of threatened species occurrence are fabricated. Also the Savage River map sheet is from 1987 and therefore does not show up to date mining structures and vegetation cover. In order to achieve more accurate results, larger scale maps, aerial photos and satellite images would be used as well as field surveys carried out to identify existing ecosystems and condition. Also several maps could be compiled, for example several stages of mining and different background layers. Also metadata and descriptions of process analysis would be added to the maps.

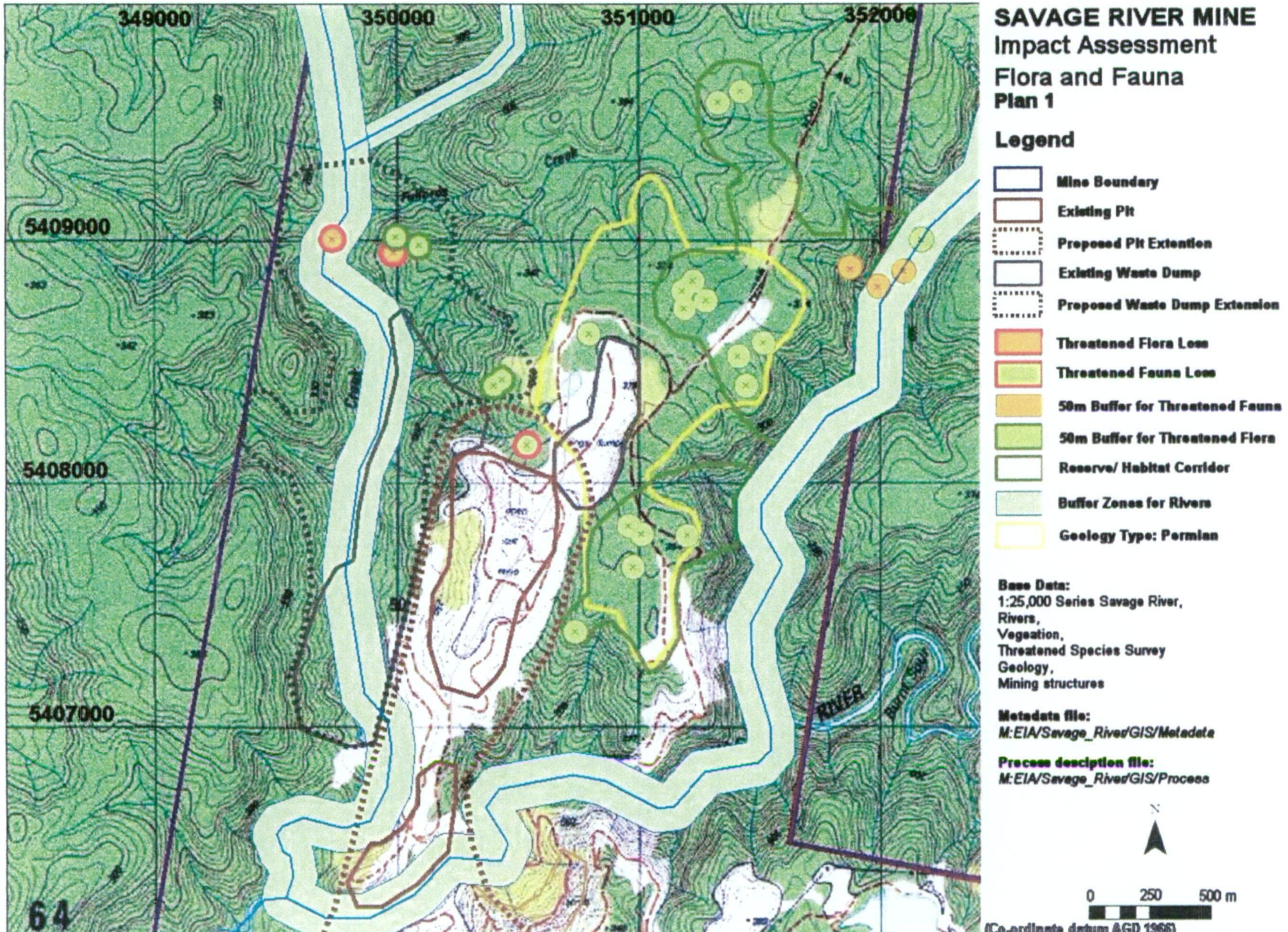

Figure 6-9: Draft map for a Flora and Fauna Impact Assessment Plan

In a next step, mitigation measures would be considered. Some areas may remain in conflict with no obvious compromise available. Mitigation measures are likely to be constrained by the location of the ore and the commonly used mining method (open-cut). This means, that in the case of development approval, some areas of existing flora and fauna are likely to be lost. This is for example the case for pits as it is impractical to refill and reshape pits to the original state. Common practice is to make slopes safe and fill the bottom of the pit with water to minimise AMD potential. Other areas such as areas of waste dumps may be re-vegetated. It is likely that re-vegetation cannot completely restore the original state and biodiversity of pre-mining ecosystems. This is especially in conflict with threatened species areas. Restoration potential using local native vegetation may be estimated from rehabilitation trials undertaken as part of the strategic plan and defined in the EIA. It may also be possible to use information from existing rehabilitation trials on similar areas. Important aspects such as recreated landform (slope and aspect), drainage, soils etc. will have a bearing on re-establishing vegetation and ultimately stable ecosystems. Thus these will be used to adjust the proposed landform design for waste dumps, pits, tailing dams etc. Experience from rehabilitation trials could be used to guide rehabilitation, which may be done progressively as proposed in accord with best practice standards in mining.

As mitigation, it may be possible to compensate the "lost" areas by reserves in other parts on the mine site. Various possible options would be identified and displayed using GIS, as a basis for decision-making on the project and conditions. Other aspects impacting on ecosystems such as the introduction and spread of weeds and diseases, in particular *Phytophthora* spp. and *Myrtle wilt* as well as fire need to be determined (ABM, 1996). This could be done by using similar overlaying methods in GIS. The final displayed or printed maps would show the mine site as well as neighbouring areas, such as the RAP area. This would put the mine in a broader context for decisions on ecology. Existing as well as planned mining structures and facilities would also be displayed.

Beside vector data analysis, raster data analysis could be undertaken. This has several advantages:

- A large number of layers can be combined, which is necessary for complex ecosystems
- DEM raster can be used and volume, slope and aspect derived

- Satellite images can be used to investigate vegetation health, moisture content etc.
- Quantitative analysis can be undertaken using scientific formulas

The resulting information layers would be linked to the other categories. As well layers from the other categories may be used in this category.

6.5.3 Discussion

This flora and fauna category can be used to demonstrate the effects of classifications. Existing and newly created data are likely to contain errors and uncertainties due to incomplete coverage, calculation errors (formulas) and false interpretation. A common problem of classifying data is, that classes are developed for a specific purpose and may not fit in other contexts (Busby 2002). The subdivision of different classes strongly influences the result. A good example is the classification of slope values. In relatively flat environments a few slopes classes may be appropriate whereas areas with extreme varying topography larger number of classes may be needed. This depends also on the use of this data layer. Beside the number of classes, the width of classes can influence the result. For example, vegetation types are unlikely to be represented correctly by using regular rainfall increments. Instead, classes may therefore be defined based on common distribution of species and actual rainfall range, which have varying increments. Areas just above or below defined thresholds are problematic. “Fuzzy classification” may be used. In fuzzy theory, class boundaries are less crisp than in available maps and conventional classification systems (Zhang and Goodchild 2002). Fuzzy classifiers are also used in interpretation of remotely-sensed imagery (Fischer 1999). The Figure below illustrates the steps in GIS-based impact assessment on ecosystems.

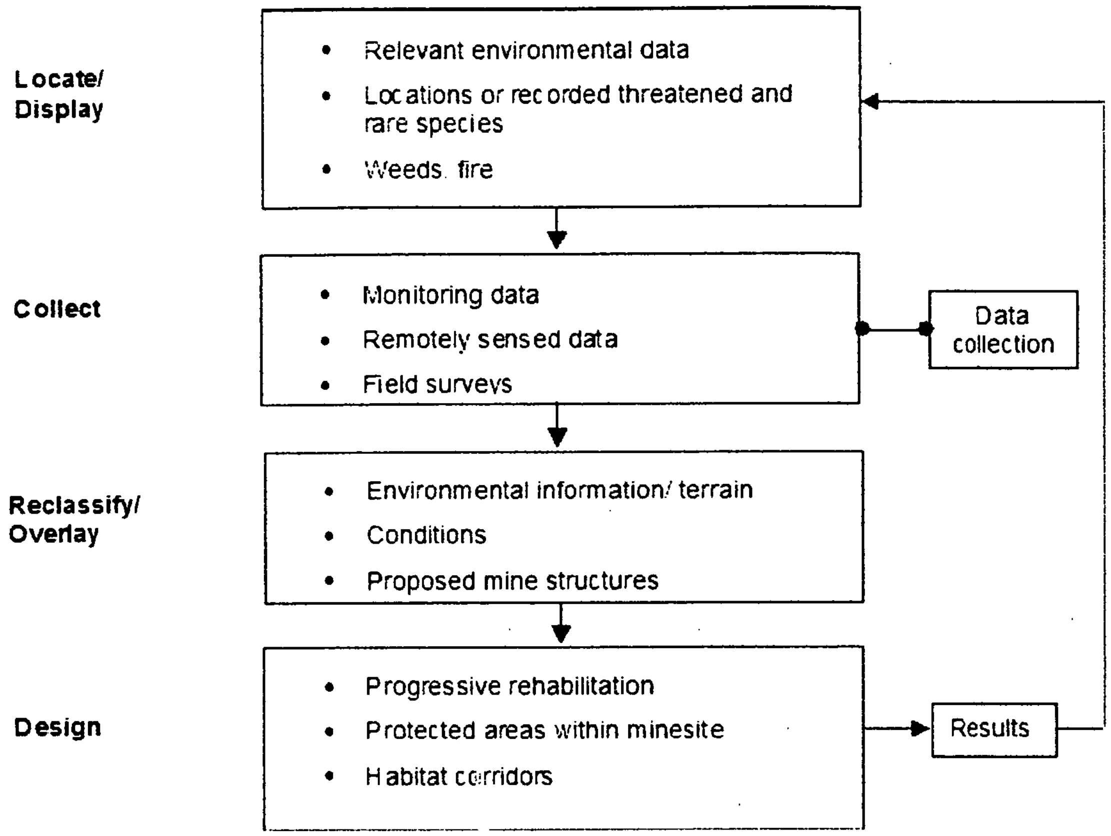

Figure 6-10: GIS process for assessment of ecosystems

6.5.4 Summary

The ecosystem of the mine lease at Savage River is an altered rainforest. It is surrounded by largely unspoilt native vegetation in neighbouring conservation areas. Beside recording the location of threatened and rare species of flora and fauna, GIS can be used to overlay these with conditions recorded from remotely sensed information and additional field surveys. Issues arising from re-classification of existing information have been discussed and methods such as Fuzzy techniques suggested to overcome the problem of fixed boundaries. Next, mitigation strategies can be designed for protected areas within the mine lease zone and habitat corridors to the surrounding land (see Figure 6-9). The extended mining area is less likely to produce a great impact on flora and fauna as this has been subject to disturbance over many years. However, progressive rehabilitation can contribute greatly to the re-establishment of a healthy ecosystem. Extensive data collection and continuous monitoring could provide the basis for future prediction models at the mine site and similar mining projects elsewhere.

6.6 Socio-economic and cultural situation

6.6.1 Impacts on the socio-economic and cultural situation

A socio-economic and cultural impact assessment is normally only required for project proposals of State significance in Tasmania (see Chapter 2). Level 2 mining activities in remote areas with no other economic activity nearby can however have a significant impact on the local community and the wider region (Nicholls 2002). This can be seen in the fluctuation of population and economy on the West coast of Tasmania, where the local industry has been dominated by the mining industry since the beginning of settlement (see unpublished census counts for population trends in SDAC, 1996). In recent years tourism mining areas have become of interest for tourism operators (see case study of Queenstown in SDAC, 1996. The Board of Environmental Management (DELM) acknowledged these effects and included assessment of socio-economic impacts for the DPEMP at Savage River. Table 6-1 gives an overview of aspects to be included in SIA and likely potential effects (after Morris, 1996). The effects can be positive or negative.

Type of impact	Potential effects
Direct economic	• Local – non-local employment • Employment characteristics (skills, type of contract, salaries etc.) • Labour supply and training
Indirect/ wider economic / expenditure	• Suppliers • Employees' expenditure • Labour market • Wider multiplier effects
Demographics	• Population size, dynamic • Characteristics (age, education, income etc.) • Settlement pattern
Housing	• Housing and tenure types • House prizes, rents • Housing problems (availability, condition etc.)
Other local services	• Education, childcare etc. • Health • Others (police, transport, recreation)
Socio-cultural	• Lifestyle, quality of life, • Social problems • Community stress

Table 6-1: Socio-economic impacts (after Morris, 1996, p. 12)

The mine may have direct effects through employment and investment. Indirect effects include attraction of other businesses and services or through needs in education and training for staff as well as by salaries and wages spent by employees. In the case of Savage River, the long existence of the mine has already established a network of local suppliers and services, which may be extended or reduced with the extension of the mine. These effects may also fluctuate over time due to management of the mine as well as outside factors such as demand on ore, prices and currency. This is especially critical if the mine is the only employer or contractor in the town or area. On the other hand, the tradition of mining on the West Coast of Tasmania for more than 150 years at various locations can be expected to be well adapted to fluctuations in the economy and employment associated with mining. Effects may also be split into local and regional.

The economic situation affects the population and vice versa. Age, education, marital status etc. of potential workers are aspects to be considered by the mining company. On the other hand the size and structure of the population is influenced by staff requirements of employers (this may change with new mining equipment and methods). Another critical factor is the housing situation. Fluctuating economic situations create more dynamic settlement pattern as can be seen in the example of Queenstown. Due to the isolated location and unpredictable future, employees may live or settle in the greater towns nearby such as Burnie and Roseberry and commute to work. As well, the mine may supply some housing in the local area for residential dormitory functions. House prices and conditions also influence the decision for housing location of potential settlers. Settlements need public services such as schools, hospitals and public transport, which may also be extended or reduced due to the economic situation. Finally, businesses can influence amenities and cultural aspects of townships.

Most of the aspects described above were covered in the DPEMP. The socio-economic situation does not contain any maps, which could enhance understanding of investors and service providers. Using GIS, results of statistical analysis such as population density and level of education (see Figure 6-11) could be displayed in thematic maps using graphs and other diagrams. Trends could be shown by using statistical data from the present and the past (Morris, 1996). As well, the township and planned improvements could be displayed to assist planning.

Another aspect, not considered in the DPEMP is the wider cultural dimension. This includes the identification of cultural heritage and other cultural values. As Savage River lies in a remote area covered in rainforest, it is unlikely that listed European historic sites or cultural heritage items will be found. This could be checked using the *Tasmanian Heritage Council Register*, the *Tasmanian Inventory of Historic places* and the *National Estate Register*. Early prospecting may have occurred and been recorded for the area, possibly associated with access along rivers. The potential of Aboriginal artefacts is registered in the DEH database. Apart from Aboriginal and European historic sites and items in the area, the mining site itself may be of cultural interest. Mining structures and facilities, that have been used over the last century may be identified and displayed on-site or relocated. The region and the wider public could benefit from access to the mine and through educational programs provided by the mine operator. Open days, talks and interpretation facilities may be used to communicate the importance of mining as well as management strategies including environmental management to the interested public. The use of GIS for socio-economic and cultural impacts assessment is explained in detail in the following section.

6.6.2 GIS analysis

GIS modelling for social sciences is less developed than for the natural environment (Wegener 2000). A common topic of modelling in social sciences is the prediction of urban developments (Yeh 1999; Frankhauser 2000; Landis and Zhang 2000). One example for a GIS model in EIA available in Tasmania is the model created to predict impacts due to different scenarios of development: for conservation, extension of forestry operations and other forms of industry (DPIE unknown). Based on employment and population characteristics a "Community Sensitivity Index" was created and the breadth (catchment) of impact calculated. One of the difficulties of the study was to determine, how people would react to change, i.e. if they would leave or to stay. Thus the establishment of variables for measuring community sensitivity were the most critical part of the model.

Precise prediction needs detailed data, analysis of the past and comprehensive knowledge of influencing factors. As described above mining is, as with other primary industries, prone to extreme fluctuation. This aspect should be integrated in the SIA by including the history of the place and previous fluctuations to show such fluctuations over time. The benefit of using GIS is its capacity to produce thematic maps, which allow planners and managers a quicker interpretation than text and tables. GIS also allows determining geographical locations and areas, pattern and distances. For a hypothetical SIA at Savage River, different layers of socio-economic and cultural aspects could be created (see Table 6-2).

GIS layer	Features	Type of mapping
Demography	• Census areas, • Population of Savage River and other towns in the area • Gender, age, education, marital status • Settlement pattern	Graduated maps[21], charts
Economic situation and trend	• Type of economy • location and distance of retailer and services	Location, graduated maps[9], charts
Direct and indirect impacts	• Investment • Employment • Area effected	Charts, catchment
Housing situation and trend	• Existing houses for sale/ rent in the area • House prices, rent	Location, charts
Township, infrastructure	• Existing and planned buildings and services	Location
Cultural heritage items and facilities	• Type and distance to recreation facilities and other amenities in the area	Location
Education	• Mine structures • History • Environmental management	Location, orthophotos, links to images, text and other media

Table 6-2: GIS layers for socio-economic and cultural impacts

Thematic maps allow the display of several layers of information, which gives faster comparison between different places than the use of tables. One method is to create a graduated map showing density (e.g. inhabitants per km^2) and charts showing absolute values or percentage (e.g. number of people or percentage of population). The map in Figure 6-11 displays population density and level of education for northwest Tasmania. The figures are based on ready available census data from 1996 (ABS 1996). This illustrates significant differences between the population centres on the coast and neighbouring census districts to the south.

[21] Choropleth map

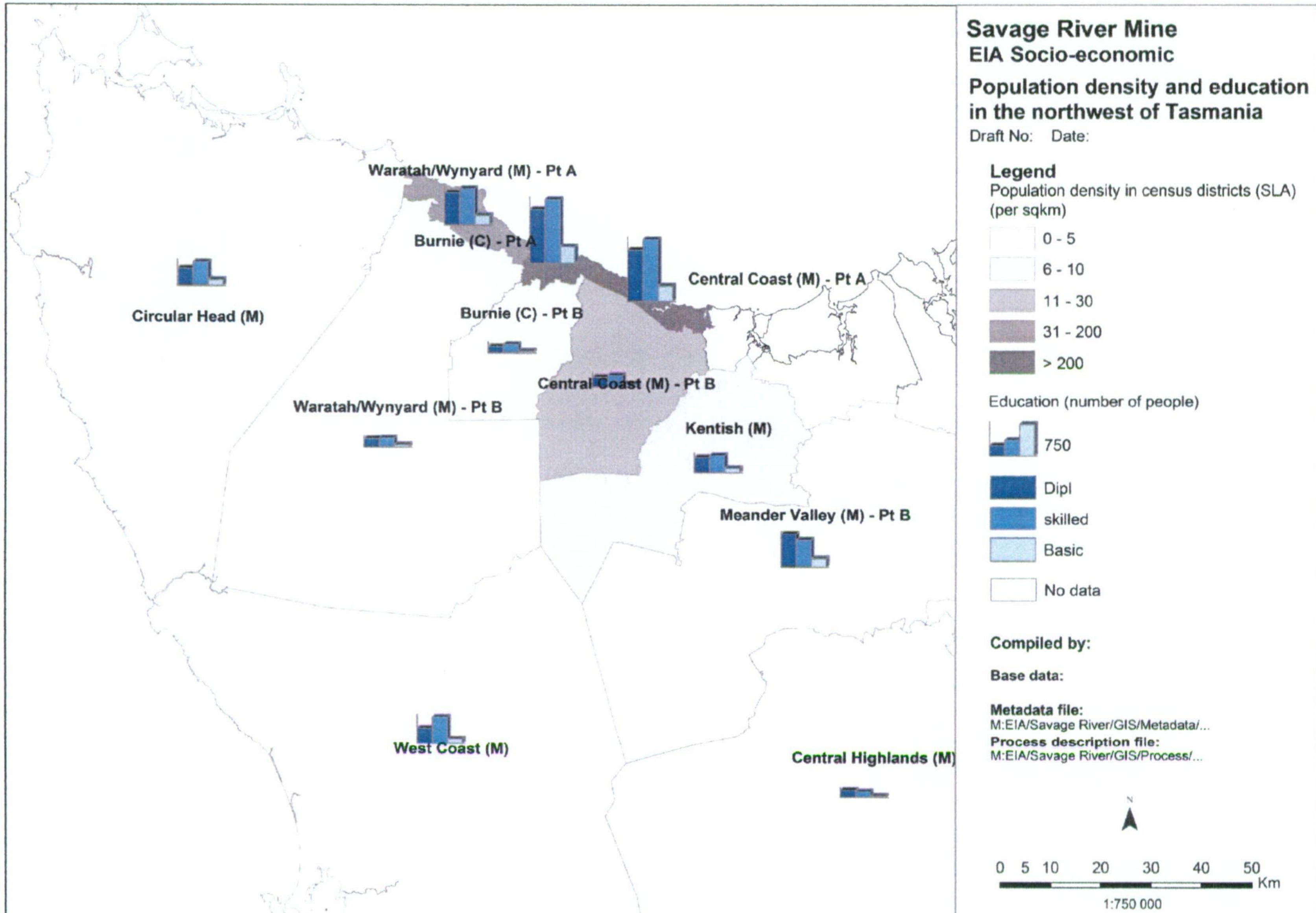

Figure 6-11: Display example for a GIS map in SIA using ArcGIS 8.3 Central Highlands

The map was produced using ArcGIS 8.3. While the program allows charts and choropleth maps to be created, some cartographic limitations were discovered for placement of diagrams and labels. Other maps may be prepared if data is available, for example percentage of mining and other economic areas in each census district or percentage of employees in mining compared to other sectors (using pie charts). Trends can be shown through use of data from different years, (number of employees in mining in 1991, 1996 and 2001). The example map above illustrates the effectiveness of combined charts and spatial display for easy comprehension at a glance.

Another type of thematic map, which assists prediction of the effect of mine re-development is to map the area affected by mining by the previous operator. This could be used to define the area influenced by the mine by using a similar approach as in the study by DPIWE (year unknown). This would however only show the previous situation. To predict future impacts the variables of change need to be known.

A further advantage of GIS is to allow the existing and planned situation to be compared directly. For example the existing situation of the township (houses and conditions) and planned upgrades can be mapped as two separate layers, which are later displayed together.

For the future, the use of GIS may be planned for interpretation and educational purposes. A simplified model of the mine could be linked with photos and interpretation. This would potentially have a positive impact on education and tourism of the region. The mine may be included on the self-guided tourist route for mining on the West Coast. Even if not realised at this stage, plans could be illustrated with samples. This could be promoted by Tourism Tasmania and in schools. It could also be of benefit for the image of the mine.

6.6.3 Summary

The use of GIS for socio-economic impact assessment has been discussed in this chapter. Socio-economic impact assessment is normally only required for projects of State significance. Mining can however have a dramatic impact on the population and employment situation in the region, especially in remote areas. Cultural aspects such as mining heritage and education could also be considered.

The benefit of GIS for socio-economic impact assessment is that several data layers from different tables can be combined. Much of the socio-economic data is available from censuses and can be obtained from ABS. An example was provided for displaying population density and education. Modelling and display of statistical data is less developed in GIS. Manual adjustments may be necessary.

6.7 Cumulative and interrelated impacts

Cumulative impact assessment accounts for additive, synenergistic or neutralising effects within a project, different projects and for different times (Chapter 2). This for example assesses the combined effects of the past and planned mining or the additive effects of different mines for the Pieman catchment. At Savage River, mining activities have left considerable impacts on the environment. According to the state wide AMD survey, the Pieman River catchment contains 558 mineral activities and 133 abandoned mines, many of them acid producing (Gurung 2001). These have caused impacts that are visible on satellite images (see Figure 5-2). Further impact can however be reduced by assessment of the existing situation and application of mitigation measures.

Cumulative and interrelated impacts can be best determined by overlays and "reclassifications". Two methods of overlays are possible: raster and vector. The raster overlay has the advantage that several themes can be compared using mathematical functions. The grid cells need to be prepared (reclassified) before an overlay is performed, to ensure that the resulting layer contains the correct values. This process can however become quite complex the higher the number of themes involved.

Vector overlaying uses "Boolean operators" (union, intersect, complement). The process is closer to a manual overlay method but can be time consuming compared to raster, as themes need to be overlaid one by one and overlays in most GIS programs are limited to "polygon-in polygon-overlay". The decision as to which method will be selected may also depend on which data type is more frequent in the datasets. Data may need to be converted.

6.8 Documentation of data and processes

A vital part of a GIS-based EIA is the documentation of data and processes. This allows transparency as well as the capacity to check for accuracy and sources of error (Guptill 1999). For example, if a vegetation map is derived from a 1:500,000 map, the information is more general in nature and therefore not very accurate and should not be combined with a 1:25,000 topographic map layer due to different levels of accuracy in these datasets. This aspect could be easily considered if datasets are properly documented (i.e. metadata are available). As the DPEMP forms the basis for decision-making of a proposal by the Board of Environmental Management, aspects such as availability of data, horizontal and vertical accuracy and GIS process are important to be recorded. This information makes the analysis results and conclusions for environmental management more completed and understandable. Also limitations and/ or chosen alternatives should ideally be included. Guidelines for documentation of GIS data based on existing standards could be provided by the Board together with guidelines on non-spatial information (i.e. text, photos etc.). Ideally, spatial information used for EIA analysis would provide metadata consisting of source, date, projection, accuracy and processing history (Guptill 1999). When using national databases such as ERIN and ASDD such information is normally provided. Governmental agencies providing data such as through *The List* deliver GIS files combined with metadata.

Beside metadata for each GIS file, the analysis process should also be documented. One way of storing and displaying GIS processes is to use flowcharts. Although discussed in GIS literature (Albrecht, Jung et al. 1997), this function is not available as a standard function in major GIS packages. However, one GIS package, which offers such a tool, is IDRISI (see Figure 6-12).

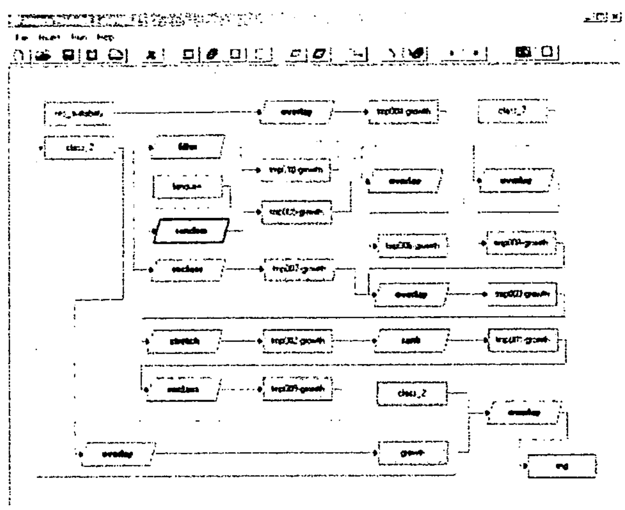

Figure 6-12: Example for process documentation in GIS (Clark Labs 2004)

In the absence of metadata entry capacity in most available GIS packages, separate metadata files may be created and flowcharts produced manually. Templates for metadata can easily be created using Microsoft Access, Excel or other software. Flowchart creation is supported for example in Microsoft PowerPoint, Word or other Office software.

6.9 Presentation of the DPEMP

GIS allows several ways of presentation and gives flexibility to choose the most appropriate ones for each situation. Forms include:

- Printed document,
- CD-ROM,
- GIS layers and
- Online

Each of these forms of presentation requires consideration of the target audience and available layout designs. The conventional DPEMP is a printed document, consisting of text, tables and maps. A CD-ROM would allow the DPEMP to be reviewed interactively, in combination with other media formats such as video and sound.

Online publication makes the DPEMP accessible to a wider audience. This could provide similar functions to CD-ROM, including interactivity and use of other presentation formats. An example may be the interactive GIS based on the EIS for the Jabiluka Uranium mine. It would also be possible to provide web-enabled GIS exploration tools, which allow selection of layers and performance of queries. This would provide more options for visualising information. Also, in EIA and environmental management using best practice standards could be displayed and promoted, which would be of benefit to the mining company.

Information on EIA practice could be of interest for other mine operators or decision makers with similar issues. By providing the EIA results online, environmental information could be stored across the industry to promote widespread improvements in standards. Also Internet-based international networks such as International "Network for Acid Prevention" (INAP, 2004) collect information on AMD worldwide. By EISs being available online, this would assist access by such networks thus giving opportunity for international review and comparison.

In the future EIA information including GIS maps and links to images and graphs could also be made available online by DPIWE. This would allow for a better understanding by the interested public of complex and abstract EIA processes than by text only as currently made available through the RPDC for projects of state significance and by the Natural Resource Network for development proposals (referrals) on Commonwealth land.

6.10 Summary and Conclusions

In the category "landscape/ landform" further analysis is needed on how to integrate post-mining landforms into the broader landscape and how landform is designed to avoid erosion and instability if affected by infrequent natural events (earthquake, flooding). The main environmental concern in the "water and soils" category is acid mine drainage (AMD) - both from previous and current mining activities. Also other types of pollution from mining and handling of hazardous material and waste disposal would be considered. For "flora and fauna" further investigations would be required into the current ecosystem and feasible rehabilitation methods. Further assessment of the socio-economic situation is necessary to ensure a prosperous and broadly accepted future of the post-mining area. Table 6-3 summarises suggested GIS analyses methods for each EIA category.

EIA Category	**GIS analysis**
Landform / landscape	Overlays (vector) Terrain analysis and design (volume, slope, aspect) Viewshed analysis (visibility) 3D displays
Pollution/ contamination	Overlays (raster) Interpolation Link to numerical models or customisation
Ecosystems	Overlays Proximity analysis/ Buffer design Creating new data layers from remotely sensed data and field inspections
Socio-economic/ cultural	Statistical maps Choropleth maps Diagrams

Table 6-3: GIS analysis methods for the EIA categories

CHAPTER 7 INTEGRATION

7.1 An integrated spatial environmental management system (ISEMS)

GIS is used as the core assessment tool with an emphasis on integration. The EIA in this approach is called ISEIA (integrated spatial environmental impact assessment). The EMS and EMP are called ISEMS (Integrated Spatial Environmental Management System) and ISEMP (Integrated Spatial Environmental Management Plan) respectively.

The integration of the EIA information into an EMS ensures a continuous process from EIA throughout the life of the mine until its close. The advantage of the use of GIS for EIA is its capacity to integrate all available data results from analysis into an EMS. This would provide a guide to monitoring and progressive rehabilitation. As all the issues need to be seen in a spatial context, GIS is an ideal tool for preparation of an EMS, where the EIA is already part of the system.

In a GIS-based approach, the EIA results form the base data for establishment of an ISEMS. After the approval has been granted, the database can be progressively expanded with data from monitoring and auditing during the operation period. Thus the EIA leads to a dynamic process instead of being a static document at one point in time (see Chapter 3). After the mine finally closes, the data can be transferred to the Municipality and other governmental agencies for ongoing management and rehabilitation if required or for monitoring only.

The following section investigates how the EIA is converted into an ISEMS. As no example exists in the literature for such conversion, the process as proposed has been based on available information and experience and can be seen as a possible example only. Figure 7-1 shows the GIS process recommended for EIA at Savage River consisting of collection and storage of data, GIS analysis of the defined categories and interrelated and cumulative effects, mitigation options and output for presentation as well as for storage in EMS.

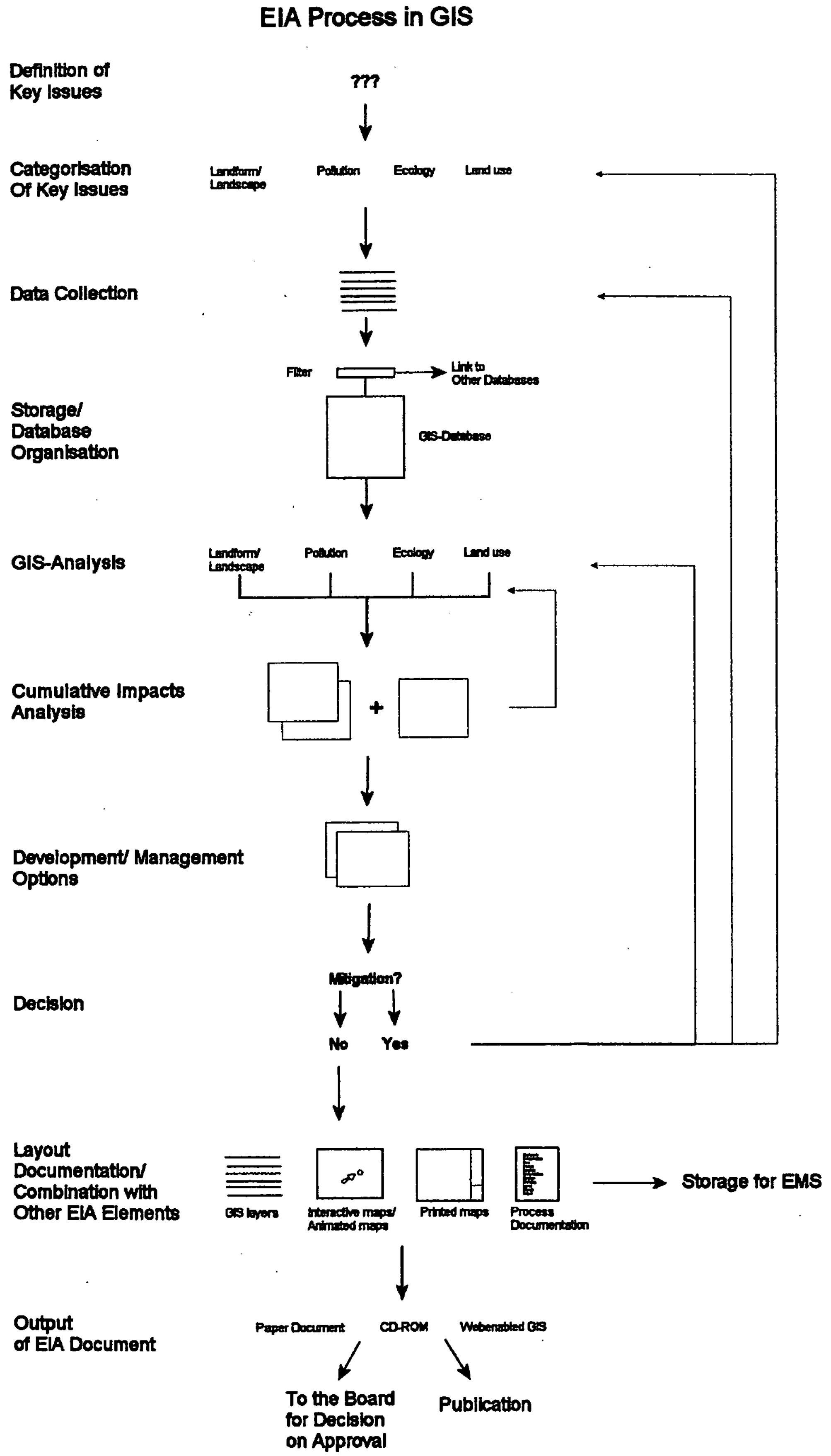

Figure 7-1: The GIS-based EIA process for Savage River

7.2 From DPEMP to ISEMS

There are several steps involved in converting an EIA into an EMS. The main ones are:

- Convert EIA categories into subsystems
- Re-develop data storage and handling
- Extend GIS functions and create links to applications
- Develop a system for documentation and publishing

7.2.1 Converting categories into subsystems

For the EIA process, data has been stored in issue related categories. These categories can also be used for environmental management. The advantage of using the same GIS system for EIA and EMS is that the same data and categorisation can be used without disruption or transfer of data flow. The categories are now part of a system and are therefore called subsystems instead of categories or folders. This results into the following subsystems:

- Contamination/ pollution monitoring (water, soil)
- Landform and landscape monitoring
- Ecosystem monitoring (re-vegetation, habitat)
- Socio-economic and cultural situation (recreation, accommodation, infrastructure etc)

During the EIA process the number of categories may have been expanded, which would consequently lead to more subsystems. As in the EIA, the subsystems are interrelated. The result of one process may influence another. Each of these four subsystems requires the input of different expert knowledge. In all four subsystems, applications and models may differ.

For environmental management, the GIS can be developed into a decision support system. For example for progressive rehabilitation, aspects need to be extracted from different subsystems and analysed. Such a system may consist of four elements as suggested by Yeh (1999): a database management system, a model-based management system, a report generator and a display generator.

A model may be developed with using variables, determined by a team of experts. For developing effective integrative models (comprising more than one subsystem), it is necessary to make the processes within each of the subsystems transparent. All steps need to be clearly documented and stored in the database. The process and result should be easy to understand in order to allow efficient decision-making by non-GIS and environmental modelling experts and later expansion or adaptation by experts in the future. Documentation may be done by using flowcharts.

7.2.2 Data storage and handling

Three aspects are vital in GIS data storage:

- Easy to locate
- Efficient in use (no duplicates)
- Conform to standards
- Stored with metadata

Spatial data used for EIA need to be stored in a way that they can be used for monitoring and further analysis. For the EIA, the best way of data storage was to store base data at a central place and GIS analysis results in issue related categories (folders). This structure can be kept for the ISEMS, as again data requirements may overlap (for example geology data in land use planning and landform). GIS data as well as metadata needs to be stored. In the ideal case, data is consistent in map scale, projection and in compliance with Australia New Zealand Information Council (ANZLIC) metadata guidelines. Data analysis processes will also need to be well documented in order to make the system transparent for all stakeholders and non-GIS experts involved.

7.2.3 GIS Functions and links

A range of GIS functions have been used for the EIA. Not all of these functions may necessary for environmental management. At the same time other functions may be needed. For example the data allows use of different GIS functions and applications. Some functions may still be required for monitoring. For example visibility studies created from a DEM or contour data may be updated with the extension of the mine or water quality modelling may be continued with monitoring data. Environmental monitoring systems and modelling programs or applications may be added for each subsystem.

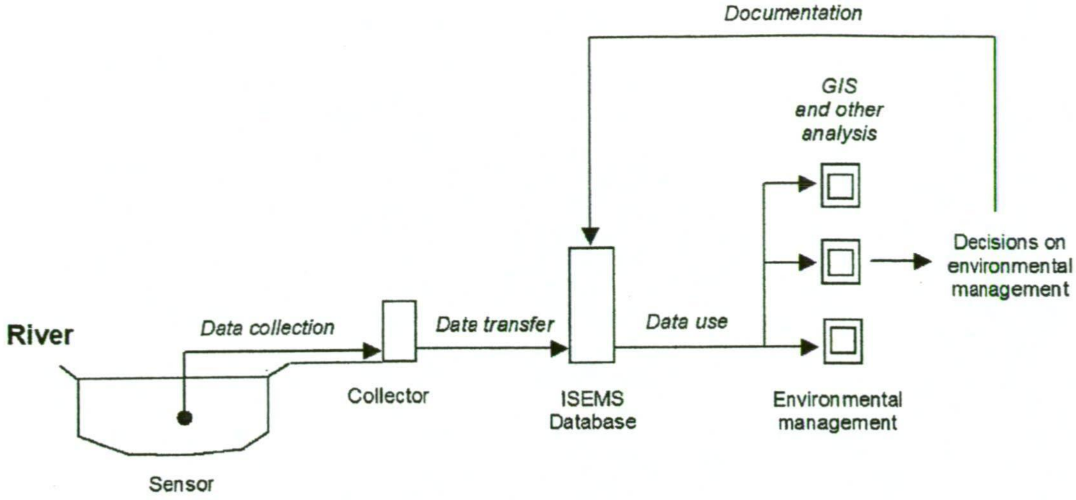

Figure 7-2: Simplified example for an environmental monitoring system

For water quality monitoring, weather stations etc. automatic sampling systems are available. Latest monitoring equipments provide palm applications (see Figure 7-3) and real time remote data collection via satellite Internet systems. The output is mainly in spreadsheet format and needs to be adjusted with the geographical location for input in GIS.

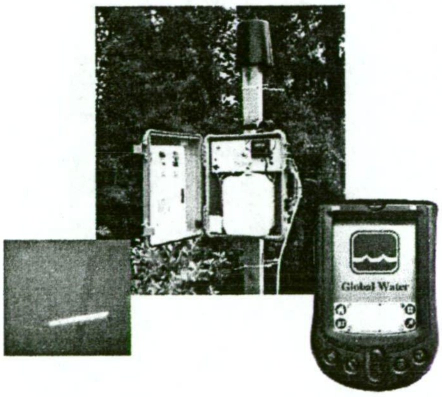

Figure 7-3: Example of water monitoring equipment[22]

Modelling applications may be developed or links to such models created. For example a link could be created to "Matlab", which is used in DPIWE for water chemistry modelling to estimate AMD (Ray 2004).

[22] Source: Global Water Instrumentation Inc., www.globalw.com/wquality.html and www.forester.net/sw_0201_stream.html 2004

7.2.4 Documentation and Publication

Best practice standards for environmental management require a regular publication of environmental monitoring, auditing and updates of development. While environmental management strategies and rehabilitation success are commonly described on websites (see Figure 7-4), a web-enabled GIS for exploring mining and environmental management on a mine site seems not to exist to date. However, this would be of great benefit to the wider public as mines can often not easily be accessed but represent large areas of environmental changes. An interactive GIS-based combination of maps, text and photos could illustrate the rehabilitation process. Well-designed maps with linked information can make spatial relationships better understandable than text and tables. Web-enabled animations could for example demonstrate stages of the mine development and progressive rehabilitation.

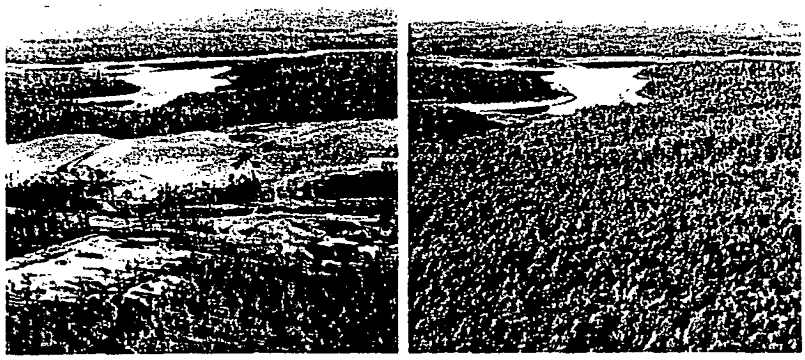

Figure 7-4: Photo presentation of rehabilitation[23]

Interactive maps could show environmental research results at abandoned mine areas undertaken in cooperation with DPIWE. This would allow the public to watch the mine development and monitor best practice standards in environmental management and post-mining land use capacities. At the same time it would promote best practice environmental communication in mining as is likely to be required by ISO 14063 after the new EMS standard has been released (see Chapter 2). Water monitoring systems for example are more commonly made available on the web (see Figure 7-5).

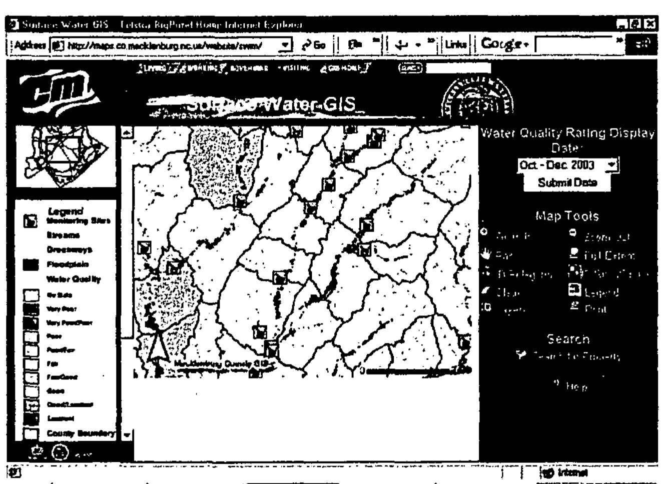

Figure 7-5 Web-enabled GIS for water monitoring in the County Mecklenburg, USA[24]

Landscape values are also becoming the focus for interactive Internet maps (The Countryside Agency and the Scottish Natural Heritage 2004). Publication of environmental management would not only show compliance with standards but also

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[23] Source: Alcoa bauxite mine in WA, www.alcoa.com/australia/en/info_page/Mine_rehab.asp 2004

[24] Source: maps.co.mecklenburg.nc.us/website/swim/

be of benefit for the image of the company as a promoter for environmentally conscious mining.

This would also allow producing a consistent dataset for every EMP (ISEMP), resulting in a continuously expanding database, which may be taken over by the next mine operator or future landowner. It also allows direct comparisons between EMPs and progressive changes.

7.3 Integration into the Tasmanian Planning System

The planning framework provides the connection between historic, current and future land use of the mine site. A wide range of options for future land use will depend on the mine lease area being left with a healthy environment. Mitigation and rehabilitation strategies are therefore vital for the region. In mining, this is usually targeted in the rehabilitation plan, as part of the development proposal. Furthermore a security bond on successful rehabilitation needs to be paid and may be used later if the developer does not comply with commitments. Best practice standards in mining require the restoration of the conditions before mining or the development of an alternative land use (EPA 1995 h). Ideally, a mining proposal would consider possible restoration of the mine areas as well as other land use options in consultation with all affected parties. This is also a principles of EMPCA (EMPCA 1994, part 5).

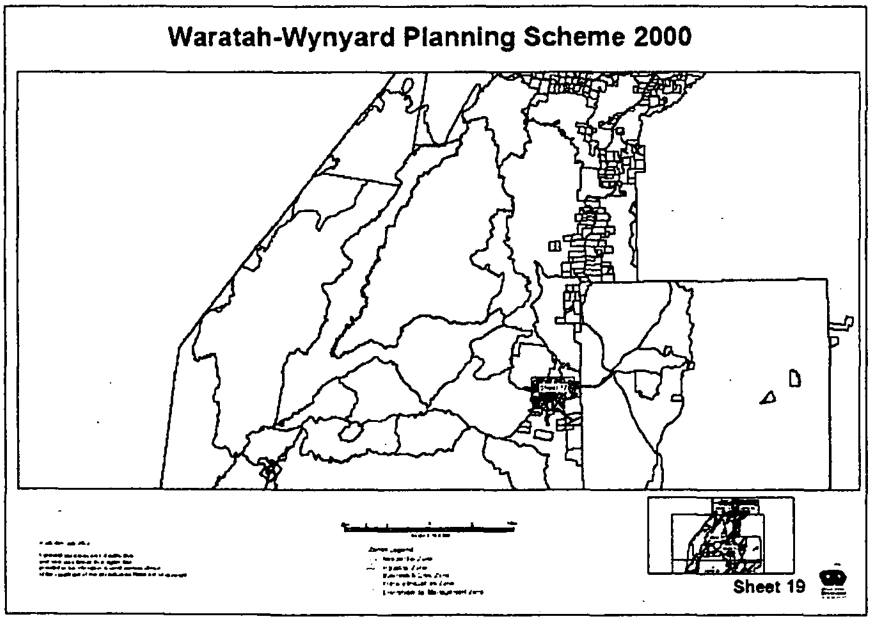


Figure 7-6: Map sheet 19 of the Waratah-Wynyard planning scheme 2000[25]

[25] Waratah-Wynyard Council (2004). Waratah-Wynyard Planning Scheme 2000. Wynyard. 21/05/2004.

There is an increasing interest from communities in Australia to obtain environmental information and be involved in local planning. An example is the "Community access and natural resources information" project in New South Wales[26]. At the same time, web-enabled GIS is found increasingly often on Council websites combining information about planning schemes and the environment. On the website of Melville (New South Wales), mapping layers of the planning scheme as well as parks, and orthophotos of the city are available for downloading (see Figure 7-7).

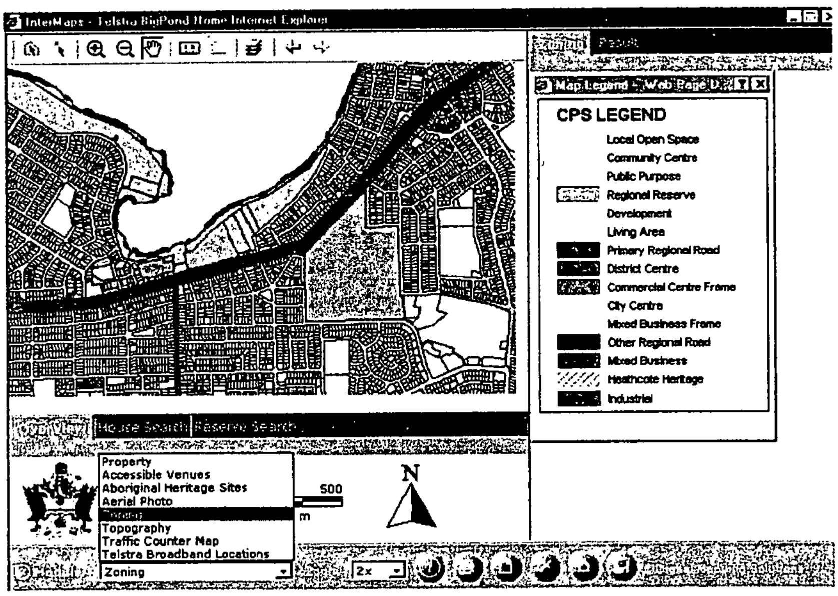


Figure 7-7: Online planning scheme[27]

By using a web-enabled GIS, locations of current development proposals could be mapped and linked with submitted planning information and details of the current review stage. Environmental information and socio-economic aspects may be made optional as background layer. A capacity for soliciting review comments from the public could be provided as well as formal survey questionnaires. This could enhance community knowledge about ongoing developments and help to reduce or avoid conflicts at a later stage. While other media such as newspapers are still useful to reach a wide audience, including those without access to the Internet, the web could

[26] CANRI 2004 *nccnsw.org.au/mapping/maps.html* viewed 10/06/2004

[27] City of Melville (2004). **2004**.

provide more detailed information combined with web-enabled GIS. Access could also be made available in public institutions such at the Council or library.

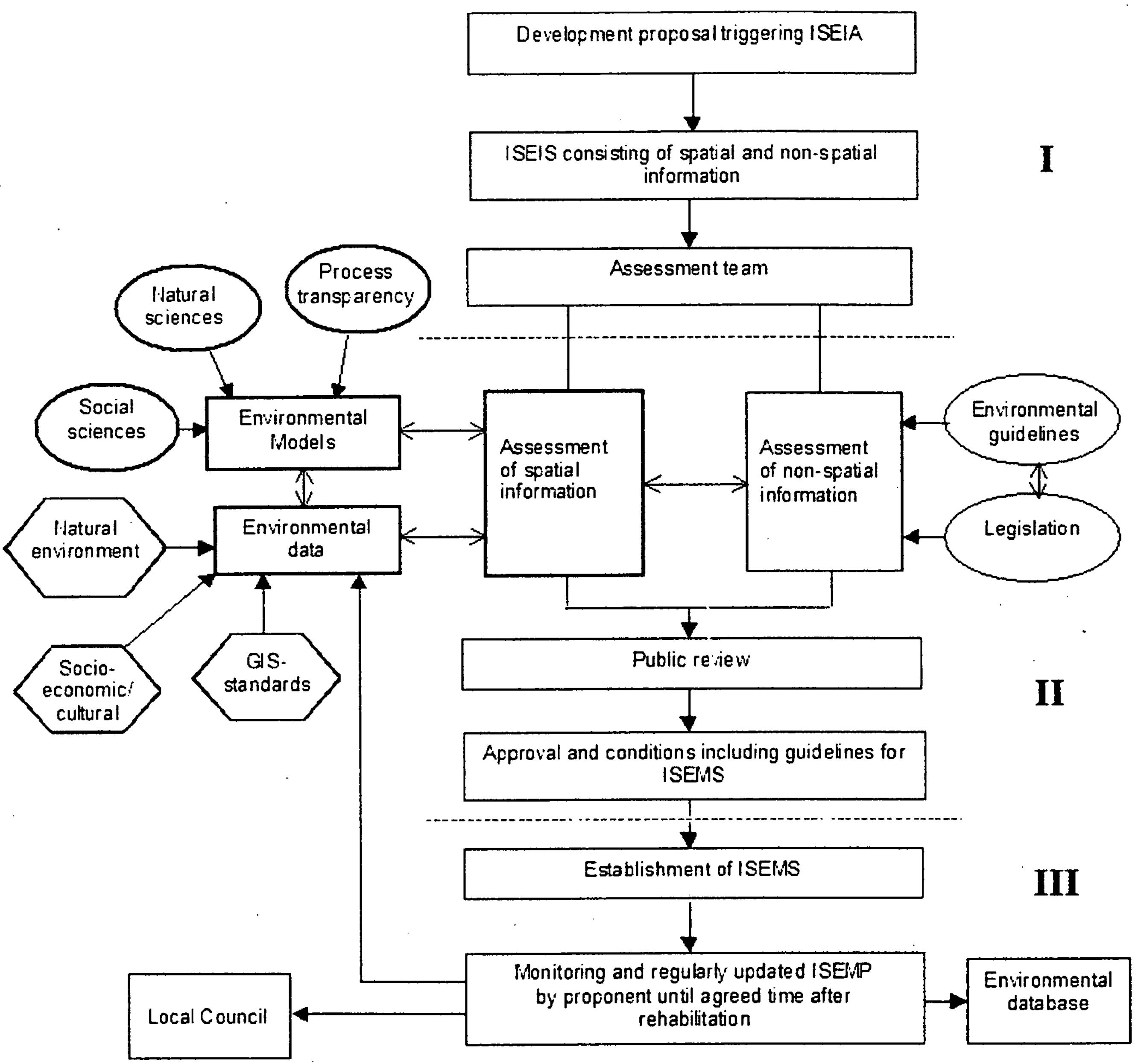
7.4 Integration of the ISEIA in the existing EIA process in Tasmania

Spatial analysis has advantages for environmental planning and management. Embedded in an EIA framework, a GIS-based approach provides the opportunity for strategic and consistent EIA assessment for one project and in respect to other similar development projects. A stronger emphasis on integrated spatial analysis in EIA would need the existing approval process to be extended by assessment of spatial components in all three stages:

- ISEIS preparation for the development proposal by the developer
- assessment by the Environmental Management and Pollution Control Board (DPIWE), public review and approval and
- establishment of an ISEMS by the operator and regular reports including maps (ISEMP).

The extended approval process is illustrated in Figure 7-8. In the first step (Part I), the ISEIA approval process would be triggered by environmental legislation and undertaken as exemplified in Chapter 6, 7 and 8. While in the existing process, the EIA significance is defined by "likelihood", in a GIS-based approach it would be done by spatial queries. These would be based on an environmental database from EIA processes, linked environmental information from various surveys as well as implemented advancing remote sensing technology. Thus it would also reduce uncertainty in determining the need for EIA. Furthermore it could target specific areas and provide continually improved guidelines from knowledge gained through similar projects. In the assessment stage (Part II), spatial and non-spatial information would be analysed. While non-spatial information is usually controlled by legislation, codes and guidelines, the spatial information would consist of checks for spatial data requirements such as scale, accuracy, timeliness etc. in consistency with national standards. Automated filtering and processing could accelerate the spatial data assessment. It would also reduce the amount of text, which dominates in conventional EIA processes (Projects of state significance such as Basslink consist of at more than 2000 pages, the DPEMP for Savage River of about 400 pages) and take longer to assess. Instead of explaining the existing situation, the text could concentrate on interpretation of analysis results, mitigation and management strategies, which would as well be supplemented with maps. To make the information understandable to decision-makers and the wider public, process transparency and presentation would be another criteria in the ISEIA assessment. These aspects would also be part of the ISEMS (established in Part III) using ISO 14063 – environmental communication.

Comments and concerns would then not only be collected and stored as text documents (see referral database at the *Environment Australia* website), but could be linked to specific locations on a map of the development area. In the final stage (Part III), the ISEMS is established. Regularly updated reports (ISEMP) would be given to the Municipality and integrated into a state-wide ISEIA database, which could be linked with other environmental databases and made accessible to the public for example through web applications. A shared ISEIA database would help to improve the ISEIA process through continuous data collection and direct comparison of processes.



ISEIA =Integrated Spatial Impact Assessment

ISEIS = Integrated Spatial Environmental Impact Statement

ISEMS = Integrated Spatial Environmental Management System

ISEMP = Integrated Spatial Environmental Management Plan

Figure 7-8: Integration of the ISEIA into the existing approval process

7.5 Recommendations for the EIA approval process in Tasmania

In order to establish a GIS-based EIA process, the following elements would be needed:

- Establish spatial analysis criteria and guidelines for the existing EIA approval system based on national spatial information standards
- Develop an automated system to check for spatial information content and accuracy in ISEIS
- Establish a state-wide EIA database with links to other environmental, socio-economic and cultural databases in the state and EIA databases of other states
- Develop web-enabled spatial queries and visualisation techniques for wider access of the database
- Develop a mechanism to regularly transfer updated environmental information from ISEMP into the ISEIA database
- Include ISO 14063 environmental communication into ISEMS guidelines
- Develop a mechanism to integrate ISEMP results planning scheme of the Municipality

CHAPTER 8 CONCLUSIONS AND FURTHER RESEARCH

During the last decade, GIS has developed into a user friendly and multi-purpose analysis tool. At the same time smaller and specialised GIS programs and applications have become available at dramatically decreased cost. This has resulted in an affordable GIS-based environmental management tool suitable for use by small and large companies involved in mining. In Tasmania, mining represents one of the most challenging EIA fields, particularly as many new mine projects follow on from previous mining operations on the same site or nearby area, as well most mines are located in remote and highly sensitive natural environments. The main advantages of GIS compared to conventional non-spatial methods are the capacity: to store and process large amounts of data; to undertake spatial analysis; and to visualise the outcome in two and three dimensional representations as well as time series. The integrated and consistent database developed during the EIA process can later be used for ongoing environmental management and reporting during the lifespan of the mine.

This study developed a theoretical EIA framework based on GIS for the iron ore mine at Savage River. The process has been divided into three steps: scoping and public consultation; key environmental impact assessment and presentation; and integration of the EIA into an environmental management system (EMS). The main steps of the scoping stage are the collection of all spatial data for the proposed mining operation, the conversion of non-spatial information into spatial data, and visualisation of all collected information for consultation with all involved parties. Environmental issues arising from the scoping process and public consultation were grouped into four issue-related categories for key environmental impact assessment: landform/ landscape; pollution/ contamination; ecosystems; and socio-economic/ cultural. For each category, specific spatial analysis and modelling tools need to be developed. For landform and landscape high resolution 3D analysis was considered for landform stability and visual effects. Time series data can be used to show changes on the landscape during different mining stages. For pollution and contamination the integration of AMD models and soil models was discussed. Hydrological modelling can already be undertaken in some GIS packages. The pollution and contamination, category involves good knowledge of geophysical and geochemical processes in order to define variables and parameters needed for 3D simulations. For the analysis of ecosystems, overlays of various environmental information such as vegetation and habitats of threatened species are most useful. In addition spatial analysis tools such as for distribution and density of features and generation of buffers can be utilised to identify key characteristics and behaviour of species. Socio-economic/ cultural impacts can be analysed by using statistical information and geostatistical tools. Data on population density and available skills in the region was used as an example.

One of the difficulties in EIA is that environmental effects are interrelated and the definition of categories always results in artificial boundaries. Interrelated and cumulative effects can best be analysed using consistent data collected over a long period of time. A consistent and integrative GIS database allows spatial analysis of various aspects over time independent of any defined categories. For the EIA at Savage River, this capacity can be used to identify effects of additional pollution on the catchment already affected by previous mining activities at Savage River and other mines in the area. The final step of the EIA is the documentation and presentation in a Development Proposal and Environmental Management Plan (DPEMP). After approval of the mining project the EIA database needs to be extended to an environmental management system for monitoring and auditing throughout the life of the mine.

Current requirements for the use of spatial information in EIA are limited to information on locations of planned mining infrastructure. The requirements should be changed to be in accordance with integrated and GIS-based procedures. This would make EIA outcomes more comparable and at the same time simplify the EIA process, as spatial data is convertible and can be used throughout the mining industry as well as by governmental agencies. It also ensures consistent reporting during the whole mining period. In addition, the data could be used for longterm state-wide environmental reporting. Such an approach requires the availability of detailed spatial and environmental data and GIS analysis tools. A state-wide freely accessible environmental database for EIA in Tasmania has been suggested. This would reduce time and cost for base data collection and the focus of the EIA could then be placed on collection of more detailed and project specific environmental information and assessment methods. Outcomes of programs such as the Savage River Rehabilitation Program (SRRP) and coordinated research projects should be used to improve environmental models for predicting impacts caused by mining. The ultimate goal should be a decision support system for EIA in mining based on quality, up-to-date environmental data and integrated spatial analysis and environmental modelling. Such a support system needs to be easy to use by non-GIS and modelling experts. It also needs to produce an outcome that is understandable for all parties affected by the mining project and it to be flexible enough to be extended to an EMS during the mining period. Up-to-date EIA procedures and methods should be used to predict and reduce environmental impacts as well as to develop environmental management strategies for the lifespan of the mine.

Further Research

This study has revealed that the use of GIS for EIA in mining is a challenging research field. While some GIS tools for analysis have been explored, more research and significant development is necessary to provide ready to use EIA tools in mining. Environmental models developed in various areas need to be tested for suitable use in mining. Integration into GIS would make the use of analysis tools easier for non-modelling experts in EIA and environmental management. This is especially of benefit in the complex area of mining, where a wide range of environmental impacts need to be considered for their accumulative interrelated effects.

For improved EIA and environmental management in mining, further research is needed in the following areas:

- Environmental effects of mining
- Environmental models for environmental impact assessment and ways of integration into GIS
- Automation of analysis processes and decision support systems for use in environmental management systems
- Visualisation techniques for communication between all parties affected by the mining project

APPENDICES

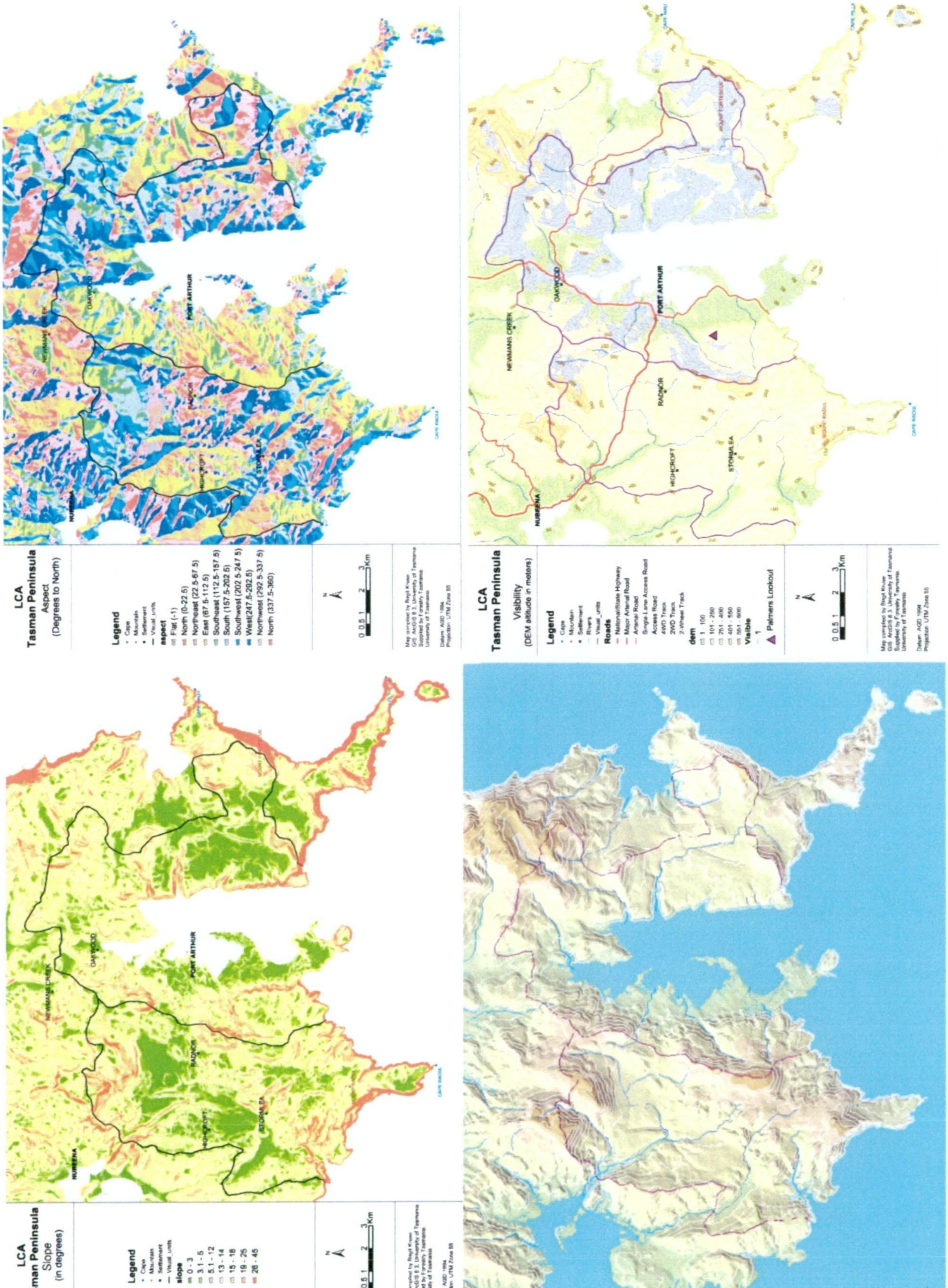


Figure 8-1: GIS layers for landscape character assessment for Tasman Peninsula in ArcGIS 8.3, from top left: slope, aspect, 3D view, visibility

Figure 8-2: Varying information content in different map scales (source: Hake 1994)

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